International Field Excursion and Workshop on Tectonic Evolution and Crustal Structure of the Paleozoic Chinese Tianshan

Yan Chen, Jacques Charvet, Michel Faure

International Field Excursion and Workshop on Tectonic Evolution and Crustal Structure of the Paleozoic Chinese Tianshan

Urumqi, China, September 9-19, 2009

Organized by

State Key Laboratory of Lithospheric Evolution
Institute of Geology and Geophysics, CAS

Xinjiang 305 Project

SUMMARY

FOREWORD

The Institute of Geology and Geophysics of the Chinese Academy of Sciences, in Beijing, together with the Xinjiang 305 Project, in cooperation with International Lithosphere Program (ILP) CC-1/4 Projects TOPO-CENTRAL-ASIA, ERAS, Chinese National 973 project and Paleo-environment research of NW China, will organize a 7-day (Sept. 10 to 16) international geological transect across the Eastern Tianshan in China, followed by a 2-day workshop* in Urumqi (Sept. 17 and 18). Integrating previous and recent field observations and laboratory analyses, the purpose of this meeting is to recognize collectively key tectonic zones, their geometric and kinematic relationships, in order to reach a common understanding on the Paleozoic evolution of the Tianshan belt and to establish the up-dated model of continental accretion of Central Asia. For practical reasons, the field trip will be limited to 25 participants, but the workshop will be open to any interested participants.

The field trip will be 7-day field observations of the key tectonic zones across the Northern, Central and Southern Tianshan. Field–based discussions of the Tianshan Belt will help to place the geodynamic evolution of this range within the general frame of Central Asian geology.

The following workshop will provide the opportunity for the international geological community to present new research results in the fields of Earth Sciences (stratigraphy, petrology, structural geology, geochemistry, geochronology, ore deposits, paleomagnetism, seismology, etc… dealing with the geological evolution of Central Asia and related areas). This meeting may provide the opportunity for elaborated syntheses on up-dated understanding of the Paleozoic evolution of the Central Asian Orogenic Belts, and also be a suitable place to set seeds for future international cooperation.

The organizing committee

* Training Center for Science and Technology Cadres, CAS Xinjiang Branch, Beijing South Road 40-7, Urumqi
  乌鲁木齐市北京南路 40 号附 7 号科技干部培训中心

ORGANIZING COMMITTEE

Qingchen Wang (IGG, CAS)
Yan Chen (ISTO, France)
Baolin Wang (305 Project, Xinjinag)
Hong Guo, (305 Project, Xinjinag)
Wei Lin (IGG, CAS)
Bo Wang (Nanjing University)
Wenjiao Xiao (IGG, CAS)
Jun Gao (IGG, CAS)

SCIENTIFIC COMMITTEE

Rixiang Zhu, Academician, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China
Qingchen Wang, Project Leader of TOPO-CENTRAL-ASIA, Chinese Academy of Sciences, Beijing, China
Yan Chen, Co-leader of TOPO-CENTRAL-ASIA, Institut des Sciences de la Terre d'Orléans, France
Alfred Kröner, Co-Leader of ERAS, University of Mainz, Germany, and SHRIMP Centre, Beijing, China
Wenjiao Xiao, Project Secretary of TOPO-CENTRAL-ASIA, Chinese Academy of Sciences, Beijing, China
Boris Natal'in, Istanbul Technical University, Istanbul, Turkey
Michel Faure, Institut des Sciences de la Terre d'Orléans, France
Jacques Charvet, Institut des Sciences de la Terre d'Orléans, France
Brian Windley, University of Leicester, United Kingdom
Bor-ming Jahn, Chief-editor of the Journal of Journal of Asian Earth Sciences, Institute of Earth Sciences, Academica Sinica
Boris Natal'in, Istanbul Technical University, Istanbul, Turkey
Jingyi Li, Chinese Academy of Geological Sciences, Beijing, China
Tao Wang, Chinese Academy of Geological Sciences, Beijing, China
Liangshu Shu, Nanjing University, China
Baolin Wang, Xinjiang 305 project, Urumqi, China
Lifei Zhang, Peking University, Beijing, China
Zhong Li, Chinese Academy of Sciences, Beijing, China

FIELD TRIP GUIDE

Geological excursion in the Paleozoic Tianshan Belt

Urumqi-Korla-Kuqa-Urumqi

10-16 September

Prepared by W. Lin (IGGCAS) and B. Wang (Nanjing University)
with the contribution of J. Charvet and M. Faure (ISTO, France)
Sponsor: SKL-IGGCAS, Topo-Central-Asia, 973 project

Part I- An outline of the geological evolution of the Paleozoic Chinese Tianshan

The Tianshan is a major orogenic domain within the Central Asian Orogenic Belt (CAOB) (e.g. Jahn et al. 2000, 2004; Jahn 2004; Xiao et al. 2004; Kröner et al. 2007; Windley et al. 2007) or Altaid orogenic collage (Sengör et al. 1993; Sengör and Natal'in 1996). It is bounded by the Kazakhstan microcontinent to the northwest, the Junggar basin to the northeast, and the Tarim basin to the south (Coleman 1989; Xiao et al. 1992; Konopelko et al. 2007; Kröner et al. 2008 and references therein, Fig. 1). It extends east-west for over 2500 km and exhibits the highest relief in Central Asia. The present topography is due to the Tertiary Asia-India collision (Tapponnier et al. 1986; Nelson et al. 1987; Avouac et al. 1993; Sobel and Dumitru 1997). In addition, the Cenozoic tectonism is responsible for the recent northward underthrusting of Tarim below South Chinese Tianshan, and for the southward underthrusting of Junggar below North Tianshan (Windley et al. 1990; Avouac et al. 1993; Hendrix et al. 1994; Burchfiel et al. 1999; Allen et al. 1999). From the Neoproterozoic to Palaeozoic, accretion of several continental blocks, island arcs and accretionary complexes to the southern margin of Eurasia formed the CAOB, within which the Tianshan Belt resulted from amalgamation of the Tarim, Junggar and Kazakhstan-Yili blocks and intervening microcontinents (Wang et al. 1994; Gao et al. 1998; Chen et al. 1999; Charvet et al. 2007; Wang et al. 2007b; Windley et al. 2007).

According to previous works (e.g. Windley et al. 1990; Allen et al. 1993; Gao et al. 1998; Chen et al. 1999), several ophiolitic belts have been used to define an Early Paleozoic South Tianshan Suture (STSS, corresponding to faults 3 and 4 in Fig. 1) and a Late Paleozoic North Tianshan suture (NTSS, corresponding to faults 1 and 2 in Fig. 1), dividing the Chinese Tianshan belt into North Tianshan, Central Tianshan and South Tianshan zones. There is often confusions in the literature between the suture zone that represents a plate boundary, and the strike-slip faults that reworked the plate boundary during Permian, i.e. after accretion and collision. In addition, the tectonic evolution of this complex orogen remains controversial, and numerous models have been proposed since the last two decades. According to Coleman (1989), the Tianshan resulted from the closure of an oceanic basin during the early Palaeozoic. Ma et al. (1993) suggested that the southern Tianshan evolved from a back-arc basin that formed by southward subduction of the Paleo-Junggar Oceanic lithosphere, whereas Cao et al. (1992) considered that the southern Tianshan represents oceanic crust thrust to the south upon the Tarim Block during the late Palaeozoic. According to Windley et al. (1990) and Allen et al. (1993), in eastern Chinese Tianshan, north-directed subduction occurred during the late Devonian-early Carboniferous along the STSS and south-directed subduction occurred in late Carboniferous-early Permian time along the NTSS. In western Tianshan, Gao et al. (1995, 1998) proposed a north-directed subduction along the southern Tianshan suture zone. According to Chen et al. (1999), the southern Tianshan originated from the closure of an early Palaeozoic ocean located between Tarim and the Central Tianshan and subsequent late Palaeozoic oblique collision.

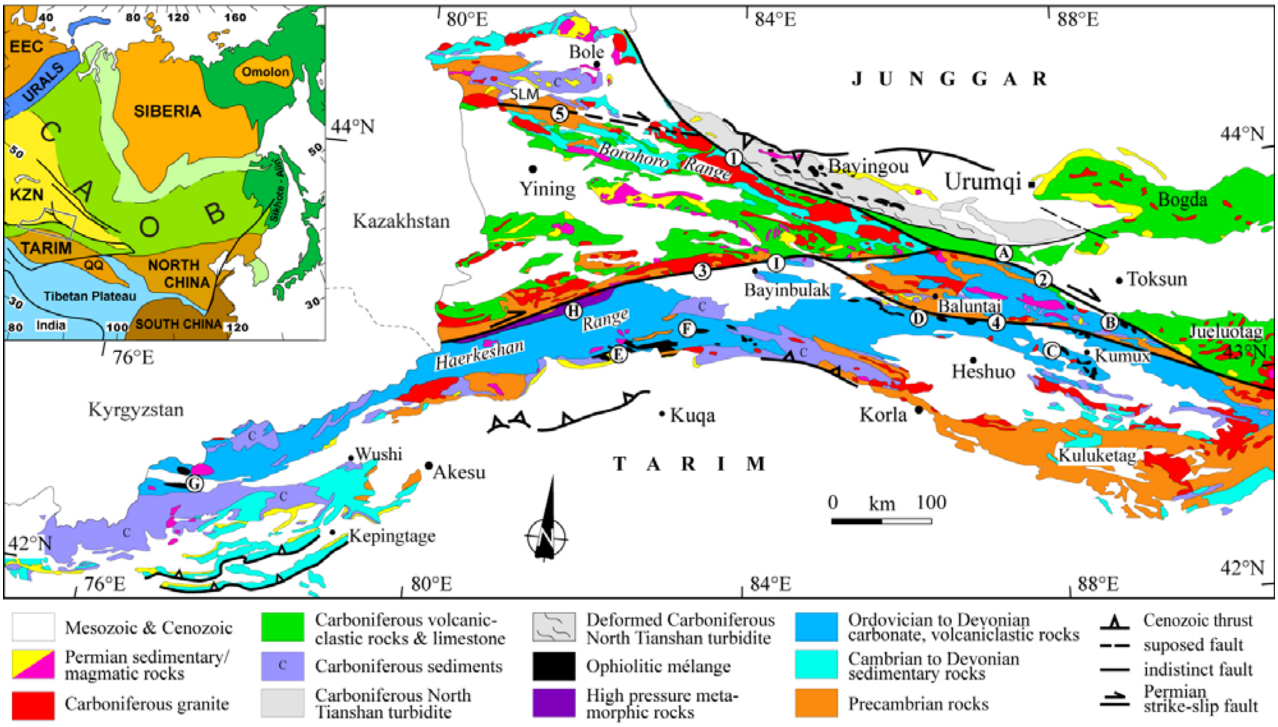


Fig. 1. Geological map of the Chinese western Tianshan belt (after Wang et al. 2008). Numbers in circle refer to the main faults: 1, North Tianshan fault (NTF); 2, Main Tianshan shear zone (MTSZ); 3, Qingbulak-Nalati fault (QNF); 4, Sangshuyuanzi fault; 5, Jinghe fault. Capital letters correspond to localities cited in text: A, Houxia; B, Gangou-Mishigou; C, Yushugou; D, Guluogou-Wuwamen; E, Heiyingshan; F, Kulehu; G, Aheqi; H, Kekesu; I, Nalati. Inset shows location of the Tianshan Belt in Central Asia (modified from Jahn, 2004). Abbreviations: CAOB, Central Asian Orogenic Belt; EEC, Eastern European Craton; KZN, Kazakhstan; QQ, Qaidam-Qinling.

The North Tianshan accretionary prism

In the North Tianshan, two lithotectonic units can be identified, namely a Carboniferous turbidite and an ophiolitic mélange (Wang *et al.* 2006; Fig. 1). The turbidites are developed in an area of 300-km long and 20-km wide and consist of sandstone and black argillite alternations. Sandstone presents typical Bouma sequences and the thickness of sandstone beds varies from a few centimeters to 1 meter (XJBGMR 1993; Wang *et al.* 2006). Terrigeneous, siliceous and calc-alkaline magmatic clasts are observed in sandstone and conglomerates, deep-water ichnofossils indicate that the turbidites were deposited in a forearc deep-sea environment (Wang *et al.* 2006). The southern part of the turbidite, along the NTF, exhibits a subvertical slaty cleavage with a subhorizontal mineral-stretching lineation. Kinematic observations indicate a dextral ductile shearing related to the NTF (Fig. 1). $^{40}Ar/^{39}Ar$ dating on biotite-rich slate indicates that the dextral shearing occurred at 275~245 Ma (de Jong et al. 2008), consistent with that of the Main Tianshan shear zone (Fig. 1; Laurent-Charvet *et al.* 2002, 2003).

The ophiolitic mélange is discontinuously developed in a 250-km long and 5~15-km wide area and crops out within the turbiditic formation. It consists of serpentinized peridotite, gabbro, diabase, basalt, chert, plagiogranite and rare limestone blocks enclosed in a sheared matrix made of black or red mudstone and light-yellow-green greywacke. Famennian-Visean microfossils have been found in cherts (Xiao *et al.* 1992; Li *et al.* 1994), and zircon U-Pb ICPMS/ SHRIMP ages of 344 ± 3 ~ 325 ± 7 Ma are obtained from Bayingou gabbro and plagiogranite (Xu *et al.* 2005, 2006a), both indicate Late Devonian to late Early-Carboniferous ages for the ophiolitic rocks. Petrological and geochemical studies show that the mafic rocks were formed in an oceanic basin (Wu *et al.* 1989; Xiao *et al.* 1992; Li *et al.*

1994). Structural analysis indicates that both blocks and matrix were deformed by north-directed shearing (Wang *et al.* 2006).

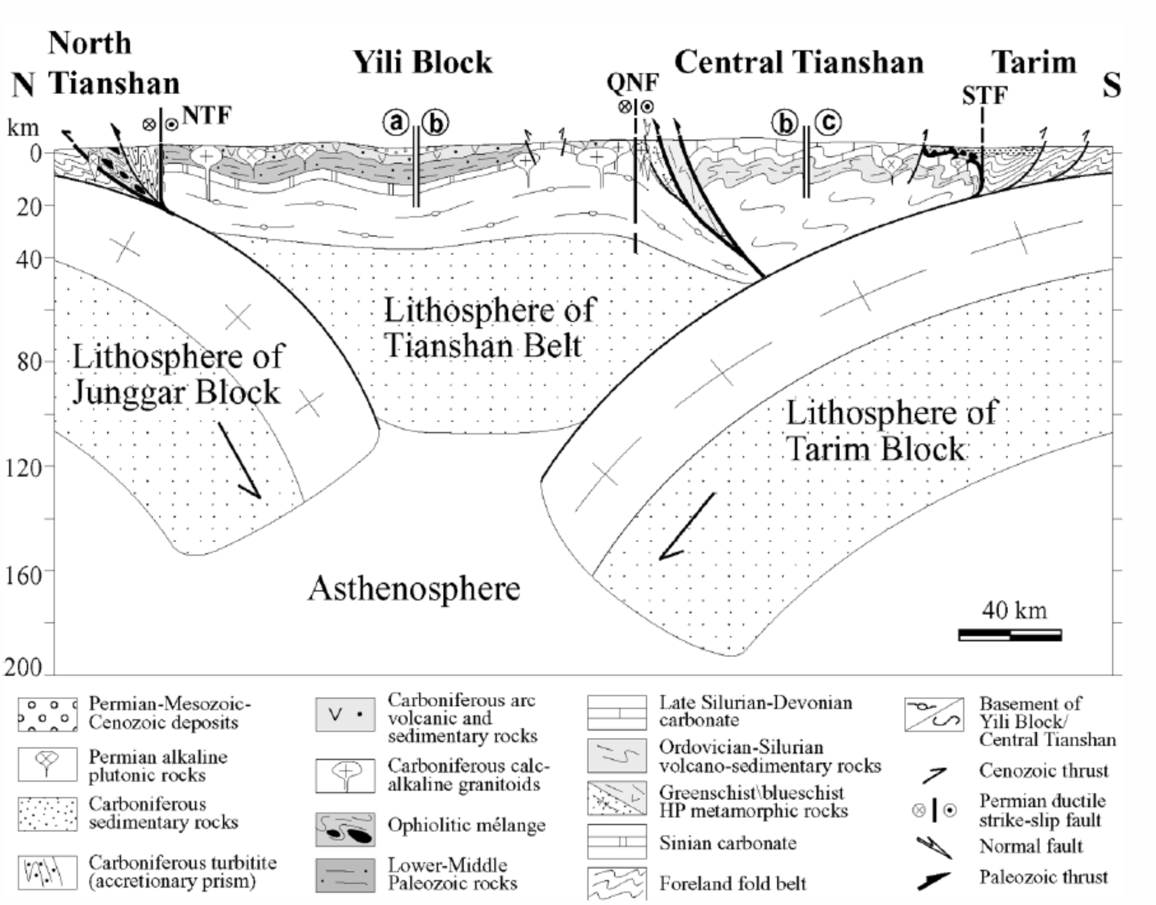


Fig. 2. – Interpretative cross section of the Yili Block and its boundaries (From Wang et al., 2008).

Yili-North Tianshan Late Paleozoic magmatic arc

In the western part, this unit is mainly composed of Carboniferous limestone and sandstone associated with andesite, rhyolite, trachyte, tuff and minor basalt (Fig. 1; XJBGMR 1992, 1993). Synchronous plutons of gabbro, granodiorite, tonalite, K-granite, pegmatite and aplite dykes are well developed. The Carboniferous rocks are lithologically similar throughout the Yili area (Fig. 1). Trace elements geochemistry and isotopic studies indicate that the magmatic rocks are calc-alkaline and were generated in an active continental margin (Chen et al. 2000a; Zhu *et al.* 2005, 2006; Wang *et al.* 2007b). Zircon U-Pb dating of the magmatic rocks (SHRIMP/ICPMS) yield 363-300 Ma ages indicating that these arc-type rocks formed during Late Devonian to latest Carboniferous (Zhu *et al.* 2005; Xu et al. 2006; Wang *et al.* 2006; Zhai *et al.* 2006; Gao et al. 2008). To the west of Urumqi, the magmatic arc is almost undeformed except locally along the Qingbulak-Nalati fault where the dextral ductile shearing occurred around 270-250 Ma (Yin and Nie 1996; Zhou *et al.* 2001). To the east, it shows north-directed structures (Laurent-Charvet 2001; Charvet et al. 2007).

The magmatic arc is situated above the Proterozoic basement and Early Paleozoic sedimentary cover. The basement rocks crop out along the boundaries of the Yili Block (Fig. 1). The Meso- to Neoproterozoic carbonates and clastic rocks of the Jixian and Qingbaikou formations are developed in the north of Borohoro range and to the south of the Yining area. The Sinian red sandstone and minor ‘‘tillite’’ (Gao et al. 1998; XJBGMR 1993; Xia et al. 2002) are exposed to the south of Sailimu Lake (Fig. 1). Precambrian amphibolite facies metamorphic rocks mainly crop out in the Bingdaban–Baluntai area, south of Urumqi. They were also recognized at Nalati Pass, north of Bayinbuluk, and in north of the Haerke Mountains (Fig. 1), and respectively dated by U-Pb method on zircon at 882 ± 33 Ma (Chen et al. 2000b) and 709 ± 13 Ma (Chen et al. 2000c). The Early Paleozoic strata are mainly developed along the northern margin of the Yili Block. Cambrian and Ordovician rocks consist of chert and carbonates, and predominantly crop out in the Borohoro range (Fig. 1).

To the east, a formation made of greywackes, red porphyritic andesites and basalts corresponds to the North Tianshan-Bogda arc, this unit is deformed by hundred-meters scale folds and south dipping reverse faults, but it disappears beneath the unconformably overlying Upper Jurassic coarse sandstones and conglomerates that can be observed along the Houxia and Toksun-Kumux sections (Fig. 1) and other parallel N-S sections more to the east (Charvet et al. 2007). The volcanic rocks of the North Tianshan-Bogda arc are often associated with Mid-Carboniferous tightly folded metre-scale beds of grey and brown fossiliferous limestone, and sandstone with minor red pelite, assigned to the Lower Carboniferous (Ma et al. 1997; Shu et al. 2000; Laurent-Charvet 2001; Xiao et al. 2004; Charvet et al. 2007). Granitic rocks are also developed in these areas and formed during Late Devonian to Carboniferous (383-310 Ma, zircon U-Pb ages) (Yang et al. 1996, 2000; Ma et al. 1997; Qin et al. 2000, 2002; Li et al. 2003). The basement of the Bogda arc is not exposed and remains unknown.

Yili-North Tianshan Block

The Yili triangular area, a microcontinent with a Precambrian basement (Allen et al. 1993), was generally considered as the western part of the Yili-Central Tianshan Plate (e.g. Xiao et al. 1992; Gao et al. 1998; Zhang et al. 2007). Whereas, it is regarded as be to constitute the "North Tien Shan-Ili Plate" in Kazakhstan and Kyrgyzstan (Mikolaichuk et al. 1995; Konopelk et al. 2007). Recent studies also suggest that in China, the Yili Block is distinct from the Central Tianshan (Wang et al. 2007, 2008; Gao et al. 2008; Qian et al. 2008). However, an ambiguity exists regarding the definition of the "Yili Block" and its boundary with the Central Tianshan. The main characteristic of this block is the presence of a series of an Upper Paleozoic (Late Devonian-Carboniferous) pile of sedimentary rocks and abundant arc volcanic and plutonic rocks, while the Central Tianshan is characterized by the occurrence of Early Paleozoic arc-type magmatic rocks and Late Paleozoic sedimentary rocks and post-collisional plutonic rocks (e.g. XJBMR 1993; Xu et al. 2006; Wang et al. 2008; Gao et al., 2008 and references therein).

South margin of Yili-North Tianshan Block HP metamorphic belt and related ophiolites

SW Chinese Tianshan (U)HP/LT metamorphic belt

The SW Chinese Tianshan HP/LT metamorphic belt mainly consists of blueschist- and greenschist-facies mafic and metapelitic rocks. Silurian marble lenses and slices of ultramafic rocks represent exotic blocks included in a mélange that is interpreted as an accretionary wedge on the southern side of the Kazakhstan-Yili Block (Gao et al. 1999). According to previous tectonic studies, the (U)HP metamorphic rocks were formed during the subduction of oceanic crust of the Tianshan paleo-ocean beneath the Kazakhstan-Yili Block (Gao et al. 1995, 1998, 2000, 2006; Volkova and Budanov 1999; Gao and Klemd 2003; Klemd et al. 2005; Zhang et al. 2007). Protoliths are MORB and OIB basalts, mafic volcaniclastic rocks, and deep-sea sediments representing an oceanic crust (Gao *et al*. 1995;

Gao and Klemd 2003). This metamorphic complex extends southwestward to Kyrgyzstan and Tajikistan (Dobretsov *et al.* 1987; Tagiri *et al.* 1995; Volkova and Budanov 1999). Kinematic analyses of these (U)HP metamorphic rocks and the underlying gneiss indicate a top-to-the-north shearing (Gao *et al.* 1995; Wang et al. 2007a; Lin et al. 2009). This northward shearing was firstly interpreted as due to the exhumation of HP metamorphic rocks (Gao *et al.,* 1995). However, according to the south dipping foliation and the kinematic consistency from HP metamorphic rocks, Proterozoic Yili basement rocks better fits the interpretation of a northward thrusting of the oceanic rocks upon the Yili continental basement (Lin et al. 2009). Radiometric ages of greenschists and blueschists reveal an important retrogression that occurred around 310 Ma (Gao and Klemd 2003; Klemd *et al.* 2005; Lin et al. 2009 and references therein). Despite the formation of an Ordovician-Devonian magmatic arc due to subduction of oceanic lithosphere (Laurent-Charvet 2001; Ma *et al.,* 2006; Charvet et al., 2007), isotopic ages for blueschists and eclogites from the HP metamorphic complex cluster closely around 350 Ma (Xiao *et al.* 1992; Gao *et al.* 1995; Gao and Klemd 2003).

The Gangou ophiolitic mélange.

Along the Toksun-Kumux transect, between the gneissic granite and the NTS Carboniferous andesites, a mélange zone is composed of several fault-bounded units. The first unit consists of a clastic and tuffaceous series, similar to the Ordovician flysch but highly schistose (S_1 N110/70S); the second unit is a mélange including various altered mafic and ultramafic rocks, and cherts blocks in a tuffaceous matrix. This ophiolitic mélange (Allen et al. 1993; Ma et al. 1997; Laurent-Charvet 2001; Guo et al. 2002; Shu et al. 2002, 2004) is a part of the accretionary prism associated with the closure of a “Tianshan Paleo-ocean” by southward subduction beneath Central Tianshan (Laurent-Charvet 2001; Charvet et al. 2001, 2004, 2007; Guo et al. 2002; Shu et al. 2002, 2003; Zhou et al. 2004; Wang et al. 2007). The formation age of this mélange is likely Devonian, as constrained by the presence of Silurian fossils in the blocks together with a Lower Carboniferous unconformity and Middle to Late Devonian plutons intruding the mélange (XJBGMR 1993; Zhu et al. 2002; Shi et al. 2007). An early slay cleavage, bearing a rarely preserved stretching lineation trending N280-250, is frequently overprinted by a steep fabric linked with strike-slip motion, especially near the contacts with granite. The contact between the mélange zone and North Tianshan Carboniferous volcanics is underlined by a cataclastic zone, with sigma-type kinematic criteria indicating a top-to-the-north motion (Charvet et al. 2007).

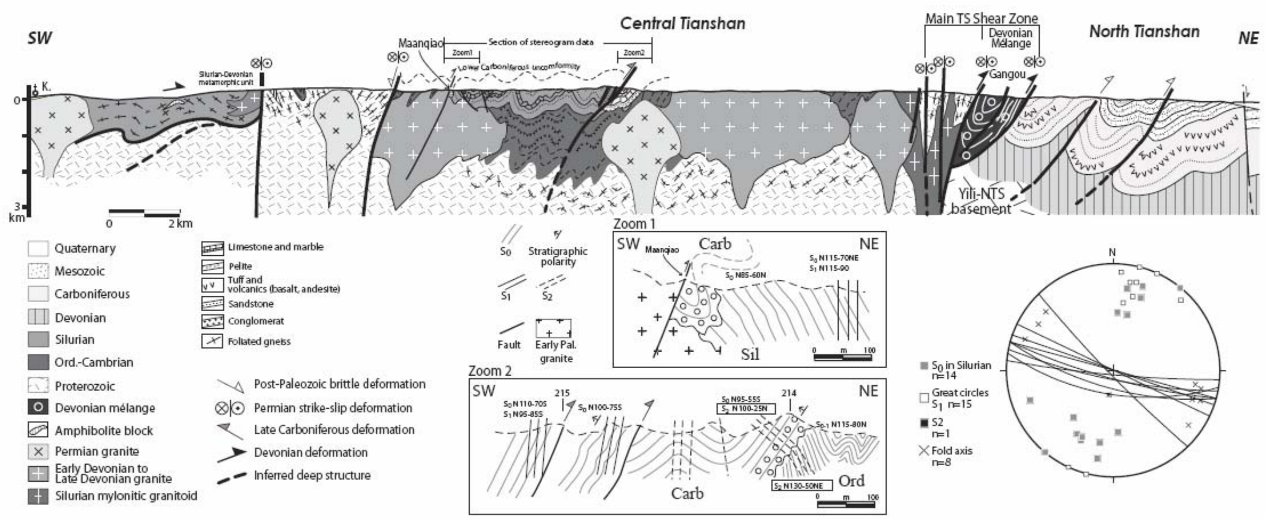


Fig. 3. Synthetic cross-section of Central and North Tianshan along the Kumux-Toksun transect (From Charvet et al. 2007).

Central Tianshan microcontinent succession and arc magmatism

To the south of the HP (or UHP) metamorphic belt, the Haerkeshan Range is made of a Paleozoic succession that was considered as the passive margin of the Tarim Plate (Windley et al. 1990; Allen et al. 1993; Carroll et al., 1995, 2001; Wang et al. 1994; Zhou et al. 2001) or a late Permian to Triassic accretionary complex (Xiao et al. 2008). However, subduction-related granitoids dated at 446~395 Ma by zircon U-Pb method crop out south of Gangou-Mishigou (Xu *et al*. 2006b), north of Kumux (Hopson *et al*. 1989), north of Baluntai (Yang *et al*. 2006) and north of Kulehu areas (Fig. 1). Furthermore, Lower Paleozoic granite gneisses (Yang et al. 2007), Ordovician- Silurian arc-type volcanic and volcaniclastic rocks are observed in Bayinbuluk and south of Gangou-Mishigou areas (XJBGMR 1993; Laurent-Charvet 2001; Ma *et al*. 2006; Charvet et al. 2007).

These Early Paleozoic magmatic and sedimentary rocks stand for the Central Tianshan arc that develop above a Precambrian basement (Wang et al. 2008). The basement rocks exposed in the southernmost part of the Haerkeshan range mainly consist of gneissic granite that formed during 707-931 Ma (zircon U-Pb; Chen et al. 2000; Zhu 2007). A high ASI value, high LILE and LREE contents, high ^{87}Sr-^{86}Sr initial ratios (0.7076-0.7096) and very low ε_{Ndt} values (-4.4~-7.7) all indicate that this gneissic granite was derived from an ancient continental basement with Nd mean crustal residence ages of 1.7-1.9 Ga and a long history prior to partial melting (Chen et al. 2000). Similar granitic gneisses occur also to the north of Kumux and Baluntai areas (Fig. 1). In addition, quartz-schist and marble are also exposed and were considered as Precambrian age (Tang et al. 1996).

In south of Bayinbuluk or north of Kumux, weakly deformed and unmetamorphosed Early to Middle Carboniferous conglomerate, sandstone and limestone unconformably overlie Pre-Carboniferous granite plutons (Hu et al. 1986, Wang et al. 1994; Zhou et al. 2001; Yang et al. 2006; Charvet et al. 2007; Wang et al. 2008; Fig. 1). Late Devonian to Carboniferous post-collisional granites also develops in these areas (Xu et al. 2006).

South Tianshan ophiolitic mélanges

In South Tianshan, the Paleozoic series that forms the backbone of the Central Tianshan microcontinent is tectonically overlain by ophiolitic mélanges, which are composed of serpentinized ultramafic rocks, gabbros, (pillow) basalts, mafic volcanic-clastic rocks, sheeted dyke, chert or siliceous mudstone and strongly sheared matrix (Shu et al. 2002; Wang et al. 2008; Lin et al. 2009; Wang et al. 2009). The geochemical features of mafic rocks suggest a back-arc basin setting (Ma et al. 1993, 2006; Dong et al. 2005; Zhu 2007; Wang et al. 2009). These ophiolite and ophiolitic mélanges were initially assumed to be rooted to the north and emplaced from north to south, onto the Tarim passive margin, after a northward stage of subduction (Windley et al. 1990; Allen et al. 1993; Gao et al. 1998; Xiao et al. 2004; Chen et al. 1999). Structural studies of the mélange and its tectonic substratum from Yushugou, Kumux and Kulehu areas indicate a top-to-the-north ductile shearing (Shu et al. 2002; Li et al. 2004; Charvet et al. 2007; Wang et al. 2008; Lin et al., 2009). Therefore, these ophiolitic rocks were considered to be originated from an oceanic basin that separated the Central Tianshan microcontinent from the northern margin of Tarim (Charvet et al., 2007; Wang et al., 2008; Lin et al., 2009; Wang et al. 2009). The flat-lying foliation and thrust contact are often deformed by south verging folds and high angle thrust faults (Li et al. 2004), but this folding is at least partly due to a Meso-Cenozoic event, since Permian sandstone is affected by the folding (Wang et al. 2008).

The mélanges have been initially assigned to the Silurian (XJBGMR 1993). However, Middle Devonian to Early Carboniferous radiolarians in a chert olistolith (Tang et al. 1995; Gao et al. 1998; Liu 2001; Zhu et al. 2007; Wang et al. 2009) argue for a latest Devonian to earliest Carboniferous age, as it is unconformably overlain by Early Carboniferous conglomerate. Recent radiometric dating confirms this assumption: Gabbroic block from Heiyingshan and pillow lava from Kulehu (Fig. 1) yield zircon U-Pb LA-ICPMS age of 392 ± 5 Ma and SHRIMP age of 425 ± 8 Ma (Long et al. 2006; Wang et al. in review), in Kumux area, the granulite of Yushugou ophiolitic body yields zircon U-Pb SHRIMP ages of 390 ± 11 Ma and 392 ± 7 Ma (Zhou et al. 2004). Therefore, the oceanic lithosphere was, at least partly, created during the Early Devonian and obducted together with HP metamorphic rocks (Liu and Qian 2003) around the Devonian- Carboniferous boundary.

North margin of Tarim block

The southernmost subunit of the Tianshan belt corresponds to the northern edge of Tarim. The Tarim block has a variably deformed and metamorphosed basement of Archean–Proterozoic to Early Paleozoic sediments (XJBGMR 1993; Hu et al. 2000; Bykadorov et al. 2003). The basement is characterized by Achaean high-grade TTG gneiss and amphibolite and Proterozoic granitic gneiss, which have Nd model ages (TDM) ranging from 3.2 to 2.2 Ga (Hu et al. 2000). The Tarim block has been mainly interpreted as a cratonic block although some different ideas exist (Hsu 1988, 1989). Sinian (Late Neoproterozoic) to Ordovician platform sedimentary rocks including limestone and shale form the lower part of the sedimentary cover (Carroll et al. 1995, 2001). The Sinian and Cambrian may contain intercalations of rift-related volcanic rocks (Xia et al. 2004). The Silurian, overlying the older rocks with a slight unconformity (Carroll et al. 1995), begins with a conglomerate and includes several polygenetic conglomeratic layers in a flysch-like series. It grades into an olistostrome, with huge olistoliths, to the south of Hongliuhe in Eastern Tianshan, marking a period of instability (Charvet et al. 2007). Upper Devonian-Lower Carboniferous arc-related plutonic rocks occur at the northern edge of Tarim (Zhu et al. 2007; Jiang et al. 2001), indicating that it acted as an active margin at that time, after being the passive margin of the back-arc basin during the Silurian-Devonian. Close to the STS boundary, Late Carboniferous to Lower Permian fluvial and marine deposits overly Sinian to Devonian rocks with an angular unconformity (Carroll et al. 1995; Wang et al. 2008). The Lower Permian strata contain rift related volcanic and volcaniclastic rocks dated at 275–280 Ma ($^{40}Ar/^{39}Ar$ ages on feldspar and U-Pb ages on zircon) and are in turn unconformably overlain by Upper Permian detrital series (Carroll et al. 1995; Chen et al. 1999; Liu et al. 2004).

Part II- Stop description (Underlined statements are interpretations by cited or Guidebook authors)

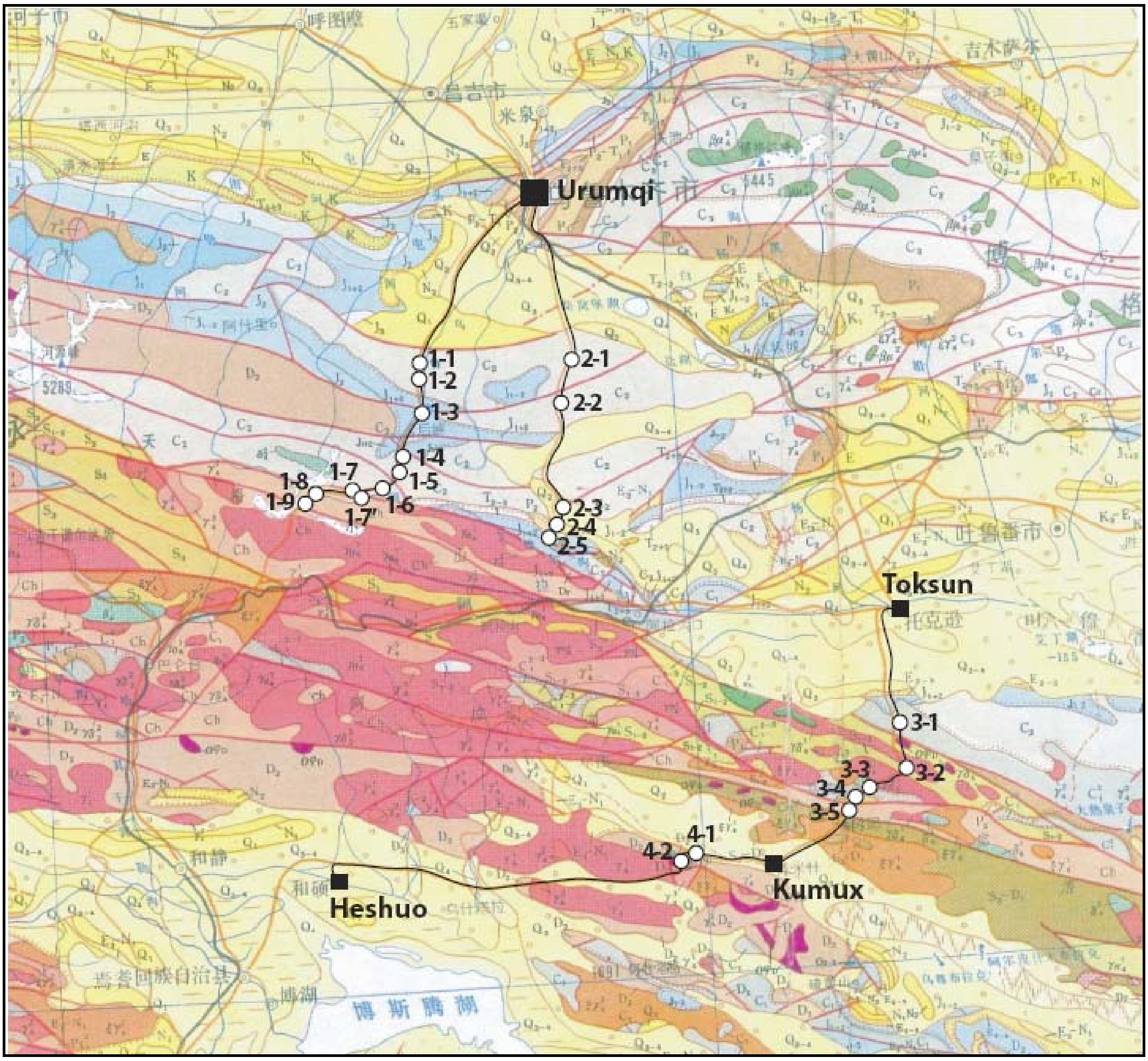


Fig. 4. Geological map and the circuit for **Days 1 to 4**.

Day 1. Urumqi-Houxia-Bingdaban section (Overnight in Urumqi)

South of Urumqi. Along Road G216, we shall observe the sedimentary rocks of the North Tianshan active margin (Carboniferous-Early Permian (zircon U-Pb SHRIMP 272±4 Ma) andesitic tuff, turbidites, chert or siliceous mudstone and pebbly mudstone). Near the mountain pass of Bingdaban, augen gneiss, foliated (or mylonitic) metavolcano-sedimentary rocks with dextral kinematic can be observed as well.

Stop 1-1: 43° 22.429'N and 87°12.426'E, between milestones 737 and 738.
Black mudstone, laminated siliceous mudstone and discontinuous sandstone beds. The bedding (S0) is folded by upright folds. En echelon tension gashes indicate south directed faulting.

Stop 1-2: 43° 21.955'N and 87° 12.108'E, after the bridge.
Subvertical turbidite. Graded bedding and cross lamination show both top-to-the north and top-to-the-south polarity. These sedimentological features argue for tight upright folds.

Stop 1-3: Immediately north of Houxia, between milestones 744 and 745
View of the flat-lying unconformity of Jurassic over Carboniferous, and open folds.

Stop 1-4 *(optional)*: 43° 07.983'N and 87° 04.633'E
Carboniferous limestone series showing vertical S_0. The present contact with the volcanic series is tectonic, but this limestone may be stratigraphically associated with the volcanics. The series is very similar to the sequence of the Yili arc.

Stop 1-5: 43°07.367'N and 87°03.801'E
Red mudstone and andesitic lava of Late Carboniferous age. This site has been studied for paleomagnetic studies (Wang, 2006).

Stop 1-6: 43°07.130'N and 87°03.044'E, south of the "Red May" bridge, milestone 774.
Fine grained diorite with skarn xenoliths. The diorite is locally mylonitic with steeply south-dipping foliation.

Stop 1-7: 43°06.880'N and 87°01.009'E
Subvertical mudstone-phyllite with a well marked subhorizontal mineral and stretching lineation.
In thin section sheared andalusite can be observed and indicates dextral shearing. This site corresponds to the North Tianshan Fault (NTF, Wang et al. 2006) and the Main Tianshan shear zone (MTSZ, Laurent-Charvet et al. 2003). Whole-rock $^{40}Ar/^{39}Ar$ dating of mylonitic phyllite yielded ages of 275-263 Ma (de Jong et al. 2008).

Stop 1-7 (optional): 43°06.880'N and 87°00.482'E, eastern side of the river
Mylonitic mica-quartz schist with steep foliation and subhorizontal stretching lineation. These rocks are the most deformed ones in the shear zone.

Stop 1-8: 43° 05.951'N and 86°50.306'E, in the curves in front of the glacier, Milestone 798
Augen gneiss with dextral kinematic indicators. The protolith is a porphyritic granodiorite dated at 441.6±3.8 Ma by SHRIMP method on zircon with inherited zircons of up to ~1788 Ma (Zhu and Song 2006). But Yang et al. (2008) recommend this augen gneiss was the basement of North Tianshan according to their geochronological result (956±11Ma).

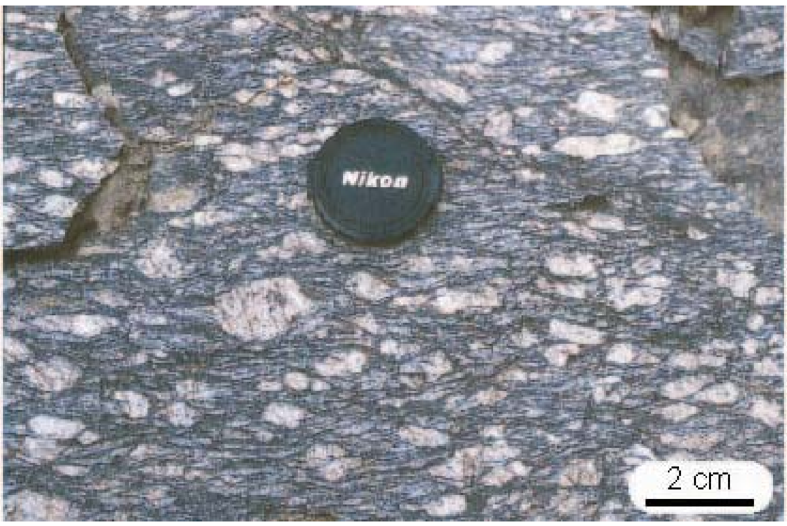


Fig. 5 Metagranite deformed by dextral shearing

Stop 1-9: Bingdaban (elevation 4280m)

Landscape on the North Tianshan range. This domain is a Carboniferous magmatic arc due to a southward subduction of the N. Tianshan Oceanic basin. The arc is afterward sheared by dextral wrenching along the MTSZ during the Permian.

Day 2. Urumqi-Aiwergou: Carboniferous olistostrome of North Tianshan, Permian alluvial sedimentary rocks and Triassic unconformity (Overnight in Toksun)

South of Urumqi. Along Road S103, this section is subparallel to the Houxia section. But the sedimentary rocks interpreted as an accretion complex are better developed. We shall observe Carboniferous pebbly mudstones, olistostrome with chert or siliceous mudstone blocks. These rocks are interpreted as trench-fill sedimentary rocks formed in the accretionary prism related to a south-directed subduction.

Stop 2-1: 43°18.839'N and 87°38.008'E, near Milestone 43

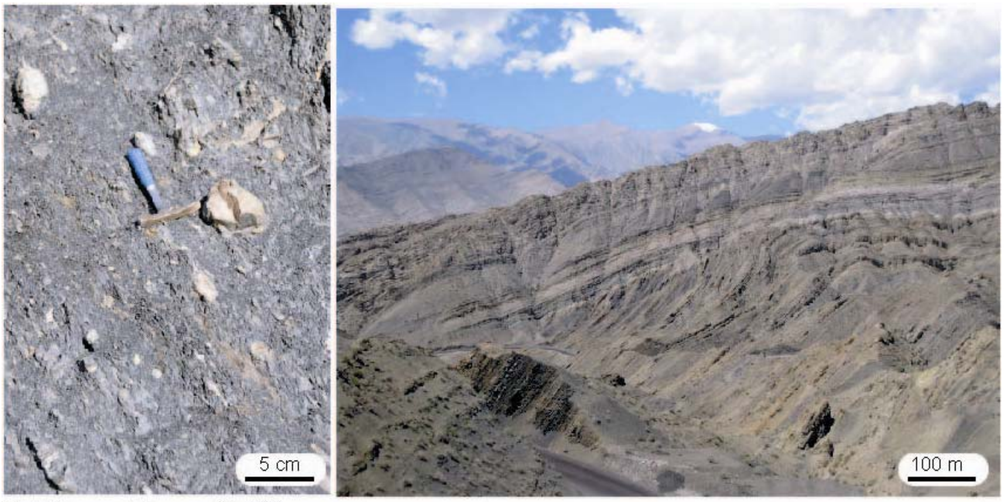
Pebbly mudstone with black matrix enclosing centimeter to plurimeter blocks of sandstone, pyroclastite, chert and limestone.

Stop 2-2: Milestone 50

Blocks-in-matrix with siliceous mudstone, chert, limestone olistoliths within the mudstone matrix.

Stop 2-3: Panorama Aiwergou, Road Z401 Milestone 2

View of subvertical Late Permian conglomerates overlain by Late Triassic terrigeneous rocks. In the background to the South, Jurassic sandstone and mudstone overly the Late Triassic beds. The southern mountains are formed by Carboniferous volcanic rocks belonging to the North Tianshan arc.



Pebbly mudstone with C2 age

Late Triassic terrigeneous rocks unconformably overlying on the Late Permian rocks

Fig. 6 photos related Day 2 excursion

Stop 2-4: in the curve of Road Z401, Milestone 6

The unconformity of Late Permian sandstone and lava upon the Carboniferous rocks cannot be directly observed there. The Late Permian rocks are folded and overturned to the south. This folding event took place before the deposition of Early Triassic conglomerates.

Stop 2-5: 43°00.894'N and 87°33.571'E

Late Triassic conglomerate consists of the pebbles of quartz, volcanic rocks and sandstone. Fluvial conglomerate unconformably overlies folded Permian sandstone.

The Late Permian, Triassic and Jurassic terrigeneous deposits or volcanic rocks that unconformably cover the Carboniferous-Early Permian arc rocks are continental formations. With some evidences of SW Chinese Tianshan (Late Permian radiolarian fossils (Li et al., 2005), UHP eclogite with Late Triassic age (Zhang et al., 2007) and Alaskan-type granite with Permian age at south Chinese Tianshan etc…) this conducts Xiao and his colleagues to conclude that the final northward subduction between Tarim and Yili blocks occurred in the Permian to Triassic (Xiao et al. 2008, 2009). However, this tectonic marker may be interpreted as a response of posterior collision events because of its sedimentary and tectonic contexts.

Day 3. Gangou section: Early Paleozoic ophiolite, arc magmatic rocks and Late Paleozoic sedimentary cover - Suture zone between Central Tianshan and Yili-North Tianshan block (Overnight in Heshuo)

In south of Toksun, along Highway G314 (direction Toksun->Kumux, i.e., N->S), this section exposes the North Tianshan volcanic arc, Gangou-Mishigou ophiolitic mélange, Ordovician to Silurian schistose volcanic and volcaniclastic rocks, Early Paleozoic arc-type granitoids and Carboniferous sedimentary rocks.

Stop 3-1: 42°35.340'N and 88°32.758'E, Milestone 184-185, at the parking near 184.5th km of the new road

Tuff, volcanic rocks with Early Carboniferous age, basalt and (red) andesites considered as the north Tianshan arc correspond to the southward subduction of the North Tianshan oceanic basin beneath the Yili-North Tianshan block during the Late Paleozoic (Charvet et al. 2007).

Stop 3-2: 42°32.673'N and 88°31.836'E, Milestone 191, by a small bridge

Mylonitic Early Carboniferous volcano-sedimentary rocks that were deformed by the Main Tianshan Shear Zone. Steeply south-dipping foliation and asymmetric clasts in the mylonitized tuff suggest dextral shearing. This shear zone separates the Early Carboniferous arc volcanic rocks to the north from the Gangou-Mishigou ophiolitic mélange and Early Paleozoic volcanic arc series to the south.

Stop 3-3: 42°32.238'N and 88°31.872'E, Milestone 192-193, by a bridge near the 192.6th km

Gangou ophiolitic mélange: blocks of metatuff, greenstone, chert, and the matrix made of greywacke. The mélange zone of ca. 30m-wide extends SEE-ward (N120).

Stop 3-3': 42°29.634' N and 88°39.440' E along the road G314 direction Kumux->Toksun (S->N), exit the main road from the 189.6th km and run to the west for 4.7 km

Gangou ophiolitic mélange: blocks of serpentinite, rondingite, chert within the matrix made of schistose tuff and greywacke. The ophiolitic mélange is intruded by SE-extending K-granitic dykes.

Stop 3-4: 42°31.406' N and 88°31.761' E, Milestone 194

Orthogneiss made of mylonitic coarse-grained K-granite and intruding dolerites dykes. The protolith was dated at 428±10 Ma (Shi et al. 2007). Dextral kinematic motion occurs along the low angle lineation.

Stop 3-5: 42°30.840' N and 88°31.098' E, Milestone 196

Slightly oriented fine-grained granite with xenoliths. Developing a visible contact metamorphism in the host-rock of Ordovician-Silurian meta-volcanic rocks, this undeformed post-tectonic granite is dated at 368±9 Ma (Shi et al. 2007).

Stop 3-6: 42°28.500' N and 88°31.462' E, Milestone 201.7 km

Schistose Ordovician basalts of the Central Tianshan arc, contact metamorphism can be observed. This is also exposed at the 200.6th km (GPS: 42°29.104' N and 88°31.741' E).

Stop 3-7: 42°23.835' N and 88°31.285' E, Milestone 212.4 km of the new road

Unconformity of Early Carboniferous conglomerate above the Ordovician metatuffs. Early Carboniferous conglomerate is overlain conformably by crinoidal limestone of Early to Middle Carboniferous. Both formations are affected by a S_2 cleavage, associated with south verging folds.

Stop 3-8: 42°22.479' N and 88°28.618' E, Milestone 217.4th km of the new road

Silurian limestone and flysch, asymmetric close folds and flat-lying shear zone suggest a north-directed movement (unfortunately, the best outcrop is now covered by cement, and only a micro-exposure is reserved).

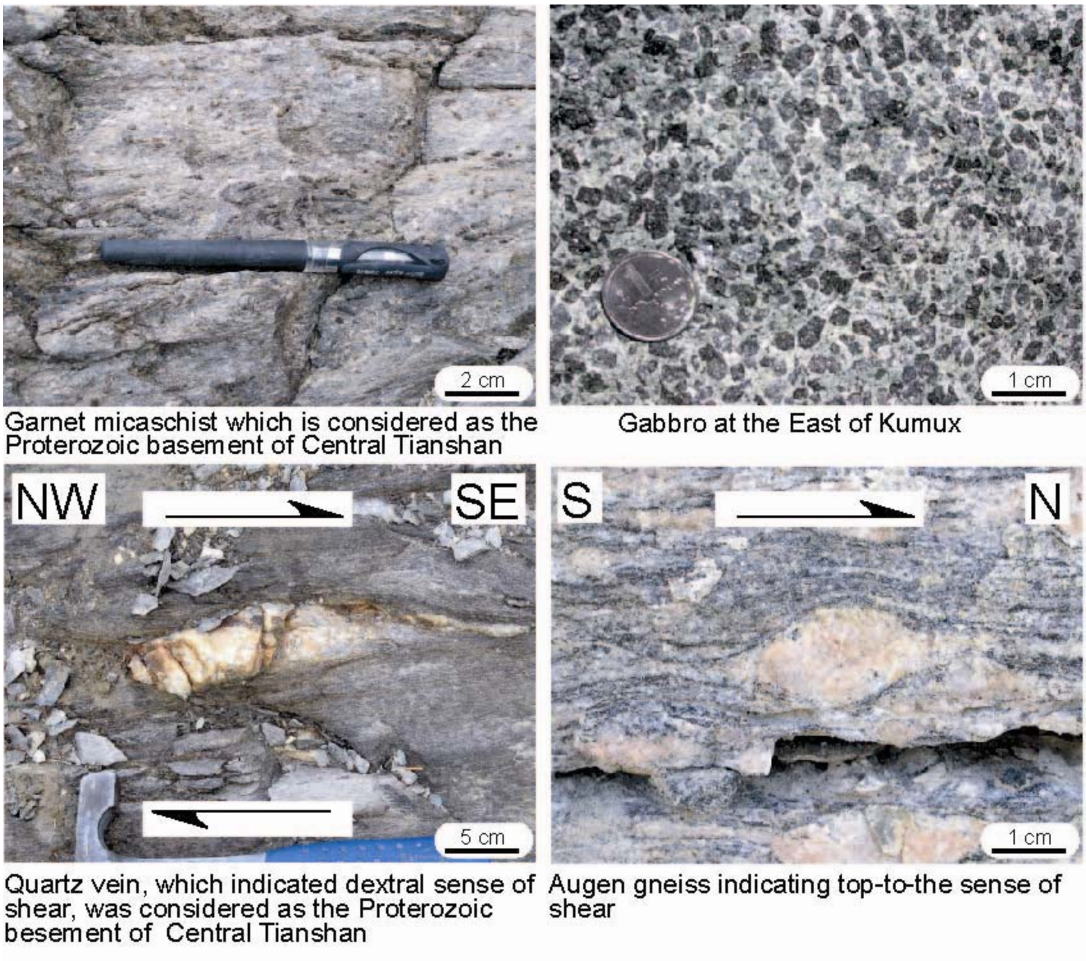


Fig. 7 Photos related the cross section of South Tuoksun

Stop 3-9: 42°22.101' N and 88°27.975' E, at Ma'anqiao, Milestone 218.7th km

Overturned Carboniferous non-schistosed red conglomerate (C_1 Ma'anqiao group) overlying Silurian fossiliferous flysch that are affected by a south-dipping cleavage. Granite pebbles are common in the conglomerate.

Stop 3-10 (optional)**:** 42°21.342' N and 88°26.796' E, Milestone 220-221 of the new road
Fault contact between Proterozoic basement (orthogneiss and migmatite) and Lower Paleozoic (Ordovician?) schists. The basement rocks are highly deformed by the Sangshuyuanzi Fault showing N120-extending vertical foliation and sub-horizontal lineation, kinematic criteria indicate a dextral sense of shearing.

Stop 3-11: 42°19.610' N and 88°24.803' E, near Sangshuyuanzi, milestone 227
Mylonitic marble and garnet micaschist, paragneiss of Xingxingxia Group that is considered as the Proterozoic basement of Central Tianshan. These rocks exhibit a vertical foliation and subhorizontal mineral and stretching lineation. The related ductile deformation indicates a dextral sense of shear, corresponding to the eastward extension of the Nalati Fault. The ^{40}Ar-^{39}Ar dating yield ages around 350 Ma (Hornblende and biotite) and 260 Ma (K-feldspar) (Yin and Nie 1996).

***Stop 3-12 (optional)**:* 42°16'57"N and 88°21.08"E, Milestone 232.8th km of the new road, on the west of the road
(This site is now inaccessible because of the wire-defence, this stop may be omitted).
Mylonitic syn-kinematic K-granite with subhorizontal stretching lineation. Sigmoidal K-feldspar shows dextral sense of shear. K-granite was dated at 254±4 Ma by zircon U-Pb ICPMS method (Wang et al. 2008b).

Day 4. Yushugou section: Pre-Carboniferous ophiolite, granulite-facies meta-mafic rocks, Top-to-the-North kinematics (Overnight in Korla)

In the west of Kumux town along the highway G314, the South Tianshan ophiolitic zone crops out in the Yushugou area where serpentinized peridotite and granulite can be observed. The Yushugou ophiolitic body and the neighboring ones, such as the Tonghuashan-Liuhuangshan mafic and ultramafic bodies are considered the ophiolitic mélanges of South Chinese Tianshan (Charvet et al. 2007).

Since the new highway runs through the Silurian-Devonian meta-flysch, and skips the ophiolitic mélange, the excursion should only be carried in this sector along the old road in direction from Heshuo to Kumux.

Stop 4-1: 42°14.001'N and 87°55.026'E, west side of a bridge at the crossing with the poor road going to an asbestos mine
Silurian meta-flysch with marble blocks. NE-dipping foliation and NE-plunging lineation are well developed, intraformal asymmetric tight folds and numerous kinematic criteria indicating a top-to-the-north shearing along a N10-N40 lineation.

Stop 4-2: 42°14.264' N 87°55.161' E, ca. 350 m to the north the stop 4-1
Basal contact of the ophiolitic melange with the highly deformed Silurian-Devonian flysch, the melange is composed of blocks of serpentinite, gabbro, basalt, chert and marble. In the matrix of the melange, greywacke and pelitic rocks were ductilely deformed with a flat lying foliation and N30-50 striking lineation. In the XZ section S-C fabric and sigmoidal clasts show a top-to-the-north sense of shear.

Stop 4-3 (optional): just before exit the Yushugou near the stop 4-4

Contact between the granulite unit and the ophiolitic mélange unit. Blocks of basalt and gabbro developed in serpentinite matrix.

Stop 4-4: 42°15.879'N and 87°54.918'E, at the NE side of the exit of the Yushugou valley

Coarse-grained granulite. The protolith of the granulite was considered as mafic volcanite (Shu et al. 2004; Zhou et al. 2004). Granulite yielded zircon U-Pb SHRIMP ages of 390 ± 11 Ma and 392 ± 7 Ma (Zhou et al. 2004), and Ca-amphibole from the granulite yielded $^{40}Ar/^{39}Ar$ ages of 368 ±5 Ma and 360 ±10 Ma, and grt+pl+ilm+WR Sm-Nd isochron age of 310 ±10 Ma (Wang et al. 2003). Zircon U-Pb ages were interpreted by Zhou et al. as the time of peak metamorphism under granulite-facies, but Wang RS et al (XXX) considered the amphibole $^{40}Ar/^{39}Ar$ ages at 370-360 as the peak metamorphism, and the Sm-Nd age of 310 Ma as the retrogression.

Stop 4-5 (optional): Milestone 280 of the old road

Roof pendant of the mélange within a granite body supposed to be Carboniferous or Permian in age, with contact metamorphism.

(This site is now along the new highway and there is no parking).

Stop 4-6 (optional): *42°15.926'N and 87°53.570'E,* at the 274.2th km of the new highway (***no parking***)

Silurian-Devonian highly deformed meta-flysch with boudinaged quartz veins, intraformal tight fold and asymmetric kinematic criteria show top-to-the-NE shearing.

Day 5. Cedaya section: Carboniferous pebbly mudstone of North Tarim (overnight in Kuqa)

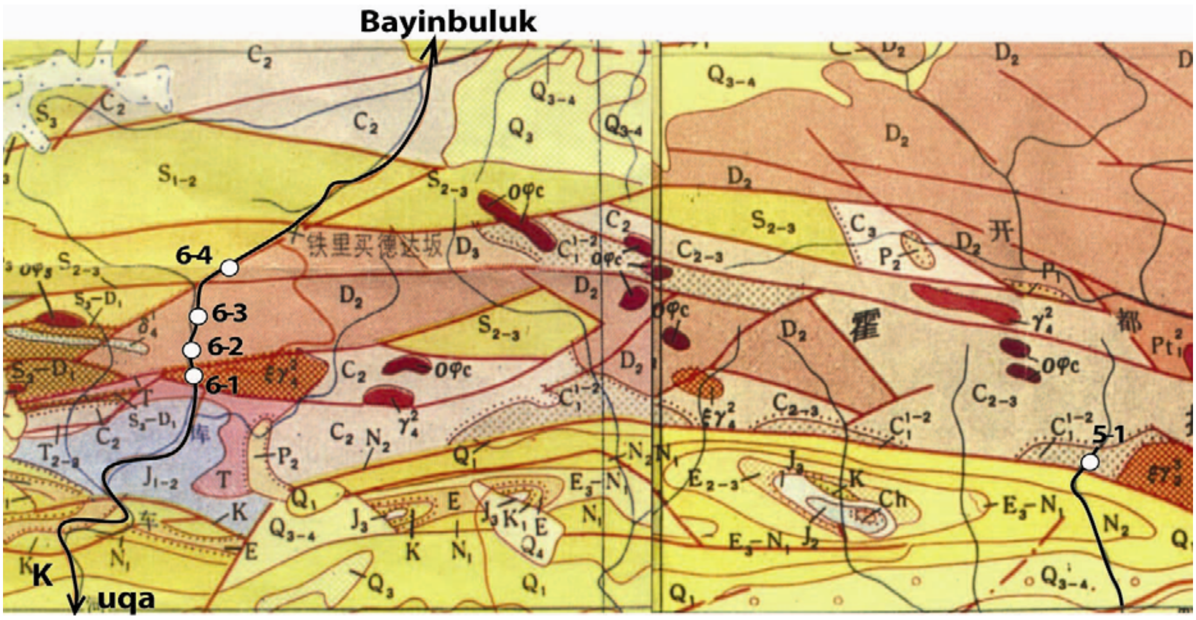


Fig. 8. Geological map and the circuit for **Days 5 and 6** in the central part of South Chinese Tianshan.

Stop 5: North of Highway G314, between Korla and Kuqa.

In this section, we shall observe a pebbly mudstone formation with the limestone pebbles. Some of the pebbles contain the coral fossil of Carboniferous age. This pebbly mudstone is interpreted as a mass flow provided from the North Tarim block.

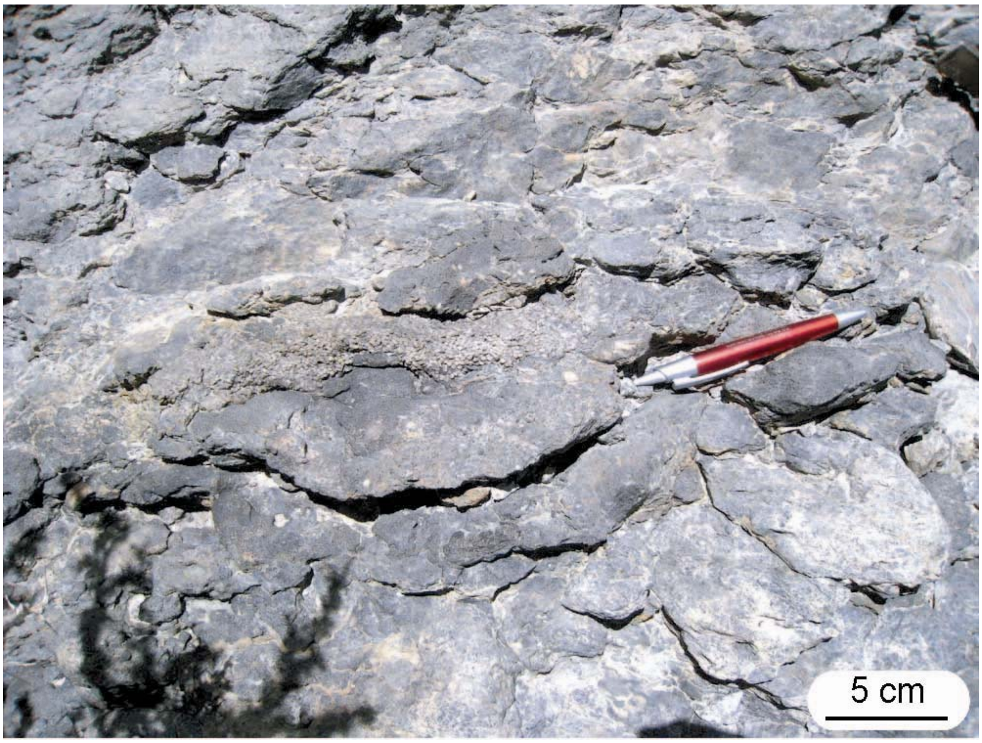


Fig. 9. Pebbly mudstone formation with limestone pebbles, which contain Carboniferous coral along the margin of North Tarim

Day 6. Du-Ku road section: Pre-C_2 ophiolitic mélange and polyphase deformation (Overnight in Kuqa)

North of Kuqa city along Road G217.
Along the bank of the Kuqa River, this section, allows us to observe the sedimentary cover of the Central Tianshan block, and the South Tianshan ophiolitic mélange overthrusted to the North.

Stop 6-1: 42°17’28”N and 83°16’39”E, near Milestone 985 of Road G217. Immediately north of the Shengli coal mine and Triassic red sediments

Magmatic arc on the northern Tarim: Diorite, granodiorite and red granite intrude mica-quartz schist of unknown age. Red granite includes diorite enclaves. Diorite yielded zircon U-Pb SHRIMP age of 387±8 Ma (Zhu 2007). All these granitoids show geochemical affinity of arc magmatism (Zhu 2007).

On the road, the arc-type granitoids contact with the Upper Permian conglomerate by a fault, but unconformity is also recognized nearby. Pebbles of granitic rocks, chert, sandstone and basalt can be identified in the Upper Permian conglomerate.

Stop 6-2: 42°23’54”N and 83°16’21”E, Milestone 968 of Road G217

Contact between the Early-Middle Devonian limestone and the schistose sandstone, which is the matrix of the Kulehu melange. North-vergent folds and faults develop in the limestone overthrusting to the north above the schist. At Milestone 967, the micaschist bearing andalusite yielded muscovite $^{40}Ar/^{39}Ar$ plateau age of 368±1 Ma (Li et al. 2004).

Stop 6-3: Kulehu ophiolitic melange

From south to north we can observe:

(1) *at 42°25’50”N and 83°15’29”E, near Milestone 963.1*,,sheared calcareous flysch and limestone (sometime marble) with disrupted bedding showing north-vergent folds;

(2) *at 42°26'24"N and 83°15'38"E, around Milestone 961.8,* radiolarian chert and siliceous mudstone with remarkable cleavage indicating north-directed shearing. Late Devonian to Early Carboniferous radiolarians were found from the chert (Tang et al. 1995; Gao et al. 1998; Zhu 2007);

(3) at *42°26'29"N and 83°15'49"E, around Milestone 963.1,* block of basalts and gabbro that have geochemical features of N-MORB, gabbro yielded zircon SHRIMP U-Pb age of 425±8 Ma (Long et al. 2006);

Stop 6-4*:* 42°26'46"N and 83°15'59"E, Milestone 959, south of the Dalaoba ("Big dragon lake")

Pillow lava blocks included in the limestone and schistose matrix.

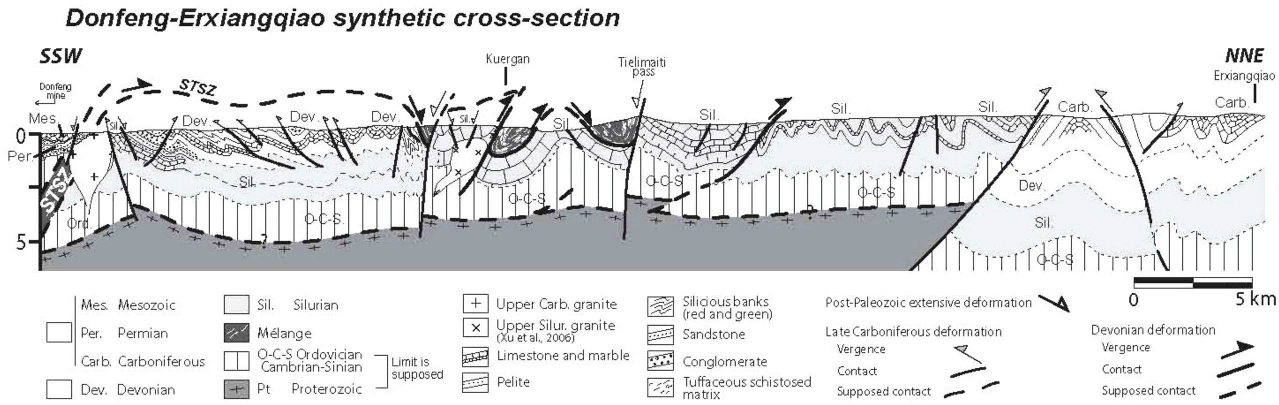


Fig. 10. synthetic crustal-scale cross-section along the Duku road (from Charvet et al., 2007).

Day X. Baiyanggou section (Southern Bogda): Early Permian pull-apart basin
(this section may be added or exchaged with another one according to the program performing)

This short section presents a complete series of magmatism and sedimentation in a pull-apart basin: olistolihs of Carboniferous limestone, Permian volcanic breccia, pillow basalt, deep water chert, flysch and mafic dykes.

Stop X-1: 43°38.368'N and 87°58.150'E, Milestone 10-11

Intrusive contact between the gabbro dykes and the host Early Permian flysch.

Stop X-2: 43°40.922'N and 88°03.129'E, 200m North of a limestone kiln

Boundary between Permian pillow basalt and the overlying sediments (chert, mudstone and siltstone).

Stop X-3: 43°41.081'N and 88°02.950'E, 100 m further north

Contact between the pillow lava and the underlined flysch-like greywacke, tuff and volcanic breccia.

Stop X-4: 43°41.154'N and 88°02.902'E

Olistostrome made of olistoliths of Carboniferous limestone with variable size and tuff matrix.

References

Allen M B, Vincent S J, Wheeler P J. 1999. Late Cenozoic tectonics of the Kepingtage thrust zone: Interactions of the Tien Shan and Tarim basin, northwest China. Tectonics, 18(4): 639-654

Allen MB, Windley BF, Zhang C. 1993. Palaeozoic collisional tectonics and magmatism of the Chinese Tien Shan, Central Asia. Tectonophysics 220:89–115

Avouac JP, Tapponnier P, Bai M, You H, Wang G. 1993. Active thrusting and folding along the northern Tien Shan and late Cenozoic rotation of the Tarim relative to Dzungaria and Kazakhstan. J Geophys Res 98:6755–6804

Burchfiel B C, Brown E T, Deng Q D, et al. 1999. Crustal shortening on the Margins of the Tien Shan, Xinjiang, China. Int Geol Rev, 41: 665-700

Bykadorov VA, Bush VA, Fedorenko OA, Filippova IB, Miletenko NV, Puchkov VN, Smirnov AV, Uzhkenov BS, Volozh YA. 2003. Ordovician- Permian Palaeogeopgraphy of Central Eurasia: development of Palaeozoic petroleum-bearing basins. Journal of Petroleum Geology 26, 325–350

Cao RL, Zhu SH, Zhu XK, Guan YB.1992. Plate and terrane tectonics of Northern Xinjiang In: Tu, G Z (ed.), New Improvement of Solid Geosciences in Northern Xinjiang (in Chinese) Science Press, Beijing, 11–26 (in Chinese)

Carroll AR, Graham SA, Chang E, McKnight CL. 2001. Sinian through Permian tectonostratigraphic evolution of the northwestern Tarim basin, China. In: Hendrix MS, Davis G (eds) Palaeozoic and Mesozoic tectonic evolution of central and eastern Asia: from continental assembly to intracontinental deformation. Geological Society of American Memoir, vol 194, pp 47–69

Carroll AR, Graham SA, Hendrix MS, Ying D, Zhou D. 1995. Late Palaeozoic tectonic amalgamation of NW China: sedimentary records of the northern Tarim, northwestern Turpan, and southern Junggar basins. Bull Geol Soc Am 107:571–594

Charvet J, Laurent-Charvet S, Shu L S, et al. 2001. Paleozoic continental accretions in Central Asia around Junggar Block: new structural and geochronological data. Gondwana Res, 4(4): 590-592

Charvet J, Laurent-Charvet S, Shu L S, et al. 2004. Paleozoic geodynamic evolution of Tianshan orogenic belt (NW China): Welding of Tarim and Junggar continental blocks. 32nd IGC -Florence, Symposium G05-09 Tethys reconstruction, Abstract vol: 155-3

Charvet J, Shu L, Laurent-Charvet L. 2007. Paleozoic structural and geodynamic evolution of eastern Tianshan (NW China): welding of the Tarim and Junggar plates. Episodes 30: 162–186

Chen JF, Zhou TX, Xie Z, Zhang X, Guo XS. 2000a. Formation of positive eNd(T) granitoids from the Alataw Mountains, Xinjiang, China, by mixing and fractional crystallization: implication for Phanernozoic crustal growth. Tectonophysics 328:53–67

Chen YB, Hu AQ, Zhang GX, Zhang QF. 2000b. Precambrian basement age and characteristics of Southwestern Tianshan: Zircon U-Pb geochronology and Nd-Sr istopic composition, Acta Petrologica Sinica, 16(1), 91-98 (in Chinese with English abstract)

Chen YB, Hu AQ, Zhang GX, Zhang QF. 2000c. Zircon U-Pb age of granitic gneiss on Duku highway in western Tianshan of China and its geological implications, Chinese Science Bulletin, 45(7), 649-653

Coleman RG. 1989. Continental growth of northwest China. Tectonics 8:621–635

De Jong K, Wang B, Faure M, Shu L, Cluzel D, Charvet J, Ruffet G. 2008. New $^{40}Ar/^{39}Ar$ age constraints on the Paleozoic tectonic evolution of the western Tianshan with emphasis on fluid ingression. Int. J. Earth Sci. DOI: 10.1007/s00531-008-0338-8

Dobretsov NL, Coleman RG, Liou JG, Maruyama S. 1987. Blueschist belt in Asia and possible periodicity of blueschist facies metamorphism. Ofioliti 12:445–456

Dong Y P, Zhou D W, Zhang C L, et al. 2005. Tectonic setting of the Wuwamen ophiolite at the southern margin of Middle Tianshan Belt. Acta Petrol Sinica, 21(1): 37-44 (in Chinese with English abstract)

Gao J, He G, Li M, Xiao X, Tang Y, Wang J, Zhao M. 1995. The mineralogy, petrology, metamorphic P-T-D-t trajectory and exhumation mechanism of blueschists, south Tianshan, northwest China. Tectonophysics 250:151–168

Gao J, Klemd R, Zhang L, Wang Z, Xiao X. 1999. P-T path of high-pressure/low-temperature rocks and tectonic implications in the western Tianshan Mountains, NW China. J Metam Geol 17:621–636

Gao J, Klemd R. 2003. Formation of HP-LT rocks and their tectonic implications in the western Tianshan Orogen, NW China; geochemical and age constraints. Lithos 66:1–22

Gao J, Li MS, Xiao XC, Tang YQ, He GQ. 1998. Paleozoic tectonic evolution of the Tianshan Orogen, northwestern China. Tectonophysics 287:213–231

Gao J, Long L L, Klemd R, et al. 2008. Tectonic evolution of the South Tianshan orogen and adjacent regions, NW China: geochemical and age constraints of granitoid rocks.Int J Earth Sci, doi 10.1007/s00531-008-0370-8

Gao J, Long L, Qian Q, Huang D, Su W, Klemd R. 2006. South Tianshan: a Late Paleozoic or a Triassic orogen? Acta Petrol Sin 22:1049–1061 (in Chinese with English abstract)

Gao J, Zhang L, Liu W. 2000. The $^{40}Ar/^{39}Ar$ age record of formation and uplift of the blueschists and eclogites in the western Tianshan Mountains. Chin Sci Bull 45:1047–1052

Guo J, Shu L S, Charvet J, Laurent C S, et al. 2002. Geochemical Features of the Two Early Paleozoic Ophiolitic Zones and Volcanic Rocks in the Central-Southern Tianshan Region, Xinjiang. Chinese J Geochem, 21(4): 308-321

Hendrix M S, Dumitru T A, Graham S A. 1994. Late Oligocene-Early Miocene unroofing in the Chinese Tian Shan: An early effect of the India-Asia collision. Geology, 22: 487-490

Hopson C, Wen J, Tilton G, Tang Y, Zhu B, Zhao M. 1989. Paleozoic plutonism in East Junggar, Bogdashan, and eastern Tianshan, NW China. EOS, Trans Am Geophy Union 70:1403–1404

Hsu KJ. 1988. Relict back-arc basins: Principles of recognition and possible new examples from China. In: Kleinspehn, K.L., Paola, C. (Eds.), New Perspectives in Basin Analysis. Springer, New York, pp. 245–263

Hsu KJ. 1989. Origin of sedimentary basins in China. In: Hsu, K.J., Zhu, X. (Eds.), Chinese Sedimentary Basins. Elsevier, Amsterdam, pp. 207–227

Hu A Q, Jahn B M, Zhang G X, et al. 2000. Crustal evolution and Phanerozoic crustal growth in northern Xinjiang: Nd isotopic evidence. Part I. Isotopic characterization of basement rocks. Tectonophysics, 328(1-2): 15-51

Hu AQ, Zhang ZG, Liu JY, Peng JH, Zhang JB, Zhao DJ, Yang SZ, Zhou W. 1986. U-Pb age and evolution of Precambrian metamorphic rocks of the middle Tianshan uplift zone, eastern Tianshan, China. Geochimica 1:23–35 (in Chinese with English abstract)

Jahn BM, Griffin WL, Windley BF. (eds.). 2000. Continental growth in the Phanerozoic; evidence from Central Asia, Tectonophysics, vol. 328, pp. 1-227

Jahn BM, Windley BF, Natal'in B, Dobretsov N. (Eds.). 2004. Phanerozoic Continental Growth in Central Asia, Journal of Asian Earth Sciences, 23: 599–815.

Jahn BM, Windley BF, Natal'in B, Dobretsov N. 2004. Phanerozoic continental growth in Central Asia. J Asian Earth Sci 23:599– 815

Jiang C Y, Mu Y M, Zhao X N, et al. 2001. Petrology and geochemistry of the intrusion belt along the northern active margin of the Tarim plate. Regional Geol China, 20(2): 158-163 (in Chinese with English abstract)

Klemd R, Brocker M, Hacker B, Gao J, Gans P, Wemmer K. 2005. New age constraints on the metamorphic evolution of the high-pressure/low temperature belt in the Western Tianshan Mountains, NW China. J Geol 113:157–168

Konopelko D, Biske G, Seltmann R, Eklund O, Belyatsky B. 2007. Hercynian post-collisional A-type granites of the Kokshaal Range, Southern Tien Shan, Kyrgyzstan. Lithos 97:140–160

Kröner A, Hegner E, Lehmann B, Heinhorst J, Wingate MTD, Liu DY, Ermelov P. 2008. Palaeozoic arc magmatism in the Central Asian Orogenic Belt of Kazakhstan: SHRIMP zircon ages and whole-rock Nd isotopic systematics. J Asian Earth Sci 32:118–130

Kröner A, Windley BF, Badarch G, Tomurtogoo O, Hegner E, Jahn BM, Gruschka S, Khain EV, Demoux A, Wingate MTD. 2007. Accretionary growth and crust formation in the Central Asian Orogenic Belt and comparison with the Arabian-Nubian shield, in Hatcher RD, Carlson MP, McBride JH, Martínez Catalán JR, (eds). 4-D Framework of Continental Crust, Geol Soc Am Mem 200: 181–209, doi: 10.1130/2007.1200(11)

Laurent-Charvet S, Charvet J, Monie P, Shu LS. 2003. Late Paleozoic strike-slip shear zones in eastern Central Asia (NW China): new structural and geochronological data. Tectonics 22:1099–1101

Laurent-Charvet S, Charvet J, Shu LS, Ma RS, Lu HF. 2002. Palaeozoic late collisional strike slip deformations in Tianshan and Altay, eastern Xinjiang, NW China. Terra Nova 14:249–256

Laurent-Charvet S. 2001. Accrétions continentales en Asie centro-orientale : évolution géodynamique etstructurale du Tianshan et du Junggar oriental (nord-ouest Chine) au Paléozoïque, Ph.DDissertation, University of Orléans, Orléans, France, 1-312

Li J Y, Xiao W J, Wang K Z, et al. 2003. Neoproterozoic-Paleozoic tectonostratigraphic framework of Eastern Xinjiang, NW China, in Mao J W, Goldfarb R, Seltmann R, Wang D H, Xiao W J, Hart C, eds, Tectonic evolution and metallogeny of the Chinese Altay and Tianshan, IGCP 473 workshop, Urumqi. International Association on the Genesis of Ore Deposits (IAGOD), CERAMS: London Natural History Museum, 2003: 31-74

Li Q, Zhang L. 2004. The P-T path and geological significance of low-pressure granulite-facies metamorphism in Muzhaerte, southwest Tianshan, Xinjiang, China. Acta Petrol Sin 20:583–594 (in Chinese with English abstract)

Li S H, Du Q. 1994. The ophiolites in Motogou-Gurt of Wusu County. Xinjiang Geology 1 (3), 265–271 (in Chinese with English abstract)

Lin Wei, Michel Faure, Yonghong Shi, Qincheng Wang, Zhong Li, 2008. Paleozoic Tectonics of Southwestern Chinese Tianshan: New insights from a structural study of the high-pressure/ low-temperature metamorphic belt. International Journal of Earth Sciences. DOI 10.1007/s00531-008-0371-7

Liu B, Qian Y. 2003. The geological characteristics and fluid evolution in the three high-pressure metamorphic belts of eastern Tianshan. Acta Geol Petrol, 19: 283-296 (in Chinese with English abstract)

Liu S W, Guo Z J, Zhang Z C, et al. 2004. Nature of the Precambrian metamorphic blocks in the eastern segment of Central Tianshan: constraints from geochronology and Nd isotopic geochemistry. Science in China (Series D), 47: 1085-1094

Liu Y. 2001. Early Carboniferous radiolarian fauna from Heyingshan south of Tianshan Mountains of China and its geological significance. Acta Geologica Sinica 75, 101–109

Long LL, Gao J, Xiong XM, Qian Q. 2006. The geochemical characteristics and the age of the Kule Lake ophiolite in the southern Tianshan. Acta Petrol Sin 22:65–73 (in Chinese with English abstract)

Ma RS, Shu LS, Sun Y. 1997. Tectonic evolution and metallogenic of eastern Tianshan Mountains. Geological Publishing House, Beijing, pp. 1-202 (in Chinese with English abstract)

Ma RS, Wang CF, Ye SF. 1993. Tectonic framework crustal evolution of Eastern Tianshan Mountains. Publishing House of Nanjing University, Nanjing, pp1–225 (in Chinese with English abstract)

Ma ZP, Xia LQ, Xu XY, Li XM, Xia ZC, Wang LS. 2006. The tectonic setting and implication of volcanic-magmatic complex from the Upper-Silurian Bayinbuluke Formation, Southern Tianshan. J of Jilin Univ 36:736–743 (in Chinese with English abstract)

Mikolaichuk AV, Kotov VV, Kuzikov SI. 1995. Structural position of the Malyi Naryn metamorphic complex as related to the problem of the boundary between the North and Median Tian Shan, Geotectonics (English translation), 29(2), 157-166

Qian Q, Gao J, Klemd R, et al. 2008. Early Paleozoic tectonic evolution of the Chinese South Tianshan orogen: constraints from SHRIMP zircon U-Pb geochronology and geochemistry of basaltic and dioritic rocks from Xiate, NW China. Int J Earth Sci, doi 10.1007/s00631-007-0268-x

Qin K Z, Sun S, Li J L, et al. 2002. Palaeozoic epithermal Au and Cu deposits in North Xinjiang, China: Epochs, features, tectonic linkage and exploration significance. Resource Geol, 52(4): 291- 300

Qin KZ. 2000. Metallogeneses in Relation to the Central Asian-style Orogeny in Northern Xinjiang. Postdoc Report. Institute of Geology and Geophysics, Chinese Academy of Sciences, pp. 1–194 (in Chinese with English abstract)

Sengör AMC, Natal'In BA. 1996. Palaeotectonics of Asia: Fragments of a synthesis. In: Yin A, Harrison TM (eds). Tectonic Evolution of Asia. Cambridge Univ. Press, Cambridge, United Kingdom, pp 486–640

Sengör AMC, Natal'in BA, Burtman VS. 1993. Evolution of the Altaid tectonic collage Paleozoic crustal growth in Eurasia. Nature 364:299–307

Shi Y R, Liu D Y, Zhang Q, et al. 2007. SHRIMP zirconU-Pb dating of the Gangou granitoids, Central Tianshan Mountains, Northwest China and tectonic significances. Chinese Sci Bull, 52(11): 1507-1516

Shu L S, Charvet J, Lu H F, et al. 2002. Paleozoic accretion-collision events and kinematics of ductile deformation in the central-southern Tianshan Belt, China. Acta Geol Sinica, 76(3): 308-323

Shu L S, Yu J H, Charvet J, et al. 2004. Geological, geochronological and geochemical features of granulites in the Eastern Tianshan, NW China. J Asian Earth Sci, 24(1): 25-41

Shu LS, Lu HF, Charvet J, Laurent-Charvet S, Yin DH. 2000. Paleozoic accretionary terranes in Northern Tianshan, NW China, Chin. Geochem., 19(3), 193-202

Sobel ER, Dumitru TA. 1997. Thrusting exhumation around the margins of the western Tarim basin during the India-Asia collision. J Geophys Res 102(B3):5043–5063

Tagiri M, Yano T, Bakirov A, Nakajima T, Uchiumi S. 1995. Mineral parageneses metamorphic P-T paths of ultrahigh-pressure eclogites from Kyrghyzstan Tien-Shan. Island Arc 4:280–292

Tang Y, Gao J, Zhang M, Wang J. 1995. The ophiolite blueschist in the southwestern Tianshan orogenic belt Xinjiang, NW China. Geological publishing house, Beijing. pp 1–133 (in Chinese with English abstract)

Tapponnier P, Peltzer G, Armijo R. 1986. On the mechainics of the collision between India Asia. In: Coward MP, Ries AC (eds). Collision Tectionics. Geol Soc London Spec Publ 19:115–157

Volkova NI, Budanov VI. 1999. Geochemical discrimination of metabasalt rocks of the Fan-Karategin transitional blueschist/greenschist belt, South Tianshan, Tajikistan: Seamount volcanism accretionary tectonics. Lithos 47:201–216

Wang B, Chen Y, Zhan Sh, Shu L, Faure M, Cluzel D, Charvet J, Laurent-Charvet S. 2007b. Primary Carboniferous and Permian paleomagnetic results from the Yili Block (NW China) and their implications on the geodynamic evolution of Chinese Tianshan Belt. Earth Planet Sci Lett 263:288–308

Wang B, Cluzel D, Shu L, Faure M, Chen Y, Meffre S, Charvet J, De Jong K. 2009. Persistence and evolution of calc-alkaline to alkaline magmatism through changing geodynamic setting: from Carboniferous convergence to Permian transcurrent tectonics, western Chinese Tianshan. Int. J. Earth Sci. DOI: 10.1007/s00531-008-0408-y

Wang B, Faure M, Cluzel D, Shu LS, Charvet J, Meffre S, Ma Q. 2006. Late Paleozoic tectonic evolution of the northern West Chinese Tianshan Belt. Geodinamica Acta 19:227–237

Wang B, Faure M, Shu L, Cluzel D, Charvet J, De Jong K, Chen Y. 2008. Paleozoic tectonic evolution of the Yili Block, Western Chinese Tianshan. Bull Soc. Géol France 179:483-490

Wang B, Shu LS, Cluzel D, Faure M, Charvet J. 2007a. Geochemical Constraints on Carboniferous Volcanic rocks of Yili Block (Xinjiang, NW China): implication on tectonic evolution of Western Tianshan. J Asian Earth Sci 29:148–159

Wang B, Shu LS, Faure, Cluzel D, Charvet J. 2007c. Paleozoic tectonism and magmatism of Kekesu-Qiongkushitai section in southwestern Chinese Tianshan and their constraints on the age of the orogeny. Acta

Petrologica Sinica, 23(6): 1354-1368 (in Chinese with English abstract)

Wang B. 2006. Paleozoic geodynamic evolution of Yili Block in West Chinese Tianshan. PhD thesis, Nanjing University-Orleans University, Nanjing-Orleans, 153 p

Wang BY, Lang ZJ, Li XD, Qu X, Li T, Huang C, Cui X. 1994. Comprehensive survey of geological sections in the west Tianshan of Xinjiang, China. Science Publishing House, Beijing. pp1–202

Wang XC, He GQ, Li MS. 1996. A discussion on the time of the Kuergan micro-massif in South Tianshan: Journal of Chengdu University of Technology, v. 23, no. 3, p. 90-95 (in Chinese with English abstract)

Windley BF, Alexeiev D, Xiao W, Kroener A, Badarch G. 2007. Tectonic models for accretion of the Central Asian orogenic belt. J of the Geol Soc Lond 164:31–47

Windley BF, Allen M, Zhang C, Zhao Z, Wang G. 1990. Paleozoic accretion Cenozoic redeformation of the Chinese Tien Shan Range, central Asia. Geology 18:128–131

Wu Jiyi and Liu Chengde. 1989. Geological features of Bayingol ophiolite complexes in North Tien Shan, Xinjiang. Acta Petrologica Sinica, 2: 76-87 (in Chinese with English abstract)

Xia Linqi, Zhang Guowei, Xia Zuchun, Xu XY, Dong YP, Li XM. 2002. Constraints on the timing of opening and closing of the Tianshan Paleozoic oceanic basin: evidence from Sinian and Carboniferous volcanic rocks. Geological Bulletin of China 21(2), 55-62 (in Chinese with English abstract)

Xia LQ, Xu XY, Xia ZC, Li XM, Ma ZP, Wang LS. 2004. Petrogenesis of Carboniferous rift-related volcanic rocks in the Tianshan, northwestern China. Geol Soc Am Bull 116(3–4):419–433

Xiao WJ, Han CM, Yuan C, Sun M, Lin SF, Chen H, Li Z, Li J, Sun S. 2008. Middle Cambrian to Permian subduction-related accretionary orogenesis of Northern Xinjiang, NW China: Implications for the tectonic evolution of central Asia. J Asian Earth Sci 32:102–117

Xiao WJ, Zhang LC, Qin KZ, Sun S, Li J. 2004. Paleozoic accretionary collisional Tectonics of the Eastern Tianshan (China): Implications for the Continental growth of Central Asia. Am J Sci 304:370–395

Xiao XC, Tang YQ, Feng YM, Zhu B, Li J, Zhao M. 1992. The tectonic evolution of North Xinjiang its adjacent regions. Geol Publ House, Beijing, 190 (in Chinese)

XJBGMR-Xinjiang, Bureau of Geology and Mineral Resources. 1993. Regional geology of Xinjiang Uygur Autonomy Region. Geol Mem Geol Pub House, Beijing, 32, pp 1–841

Xu X Y, Li X M, Ma Z P, et al. 2006a. LA-ICPMS zircon U-Pb dating of gabbro from the Bayingou Ophiolite in the northern Tianshan Mountains. Acta Geol Sinica, 80(8): 1168-1176 (in Chinese with English abstract)

Xu X Y, Ma Z P, Xia L Q, et al. 2005. SHRIMP dating of plagiogranite from Bayingou ophiolite in the northern Tianshan Mountains. Geol rev, 51(5): 523-527 (in Chinese with English abstract)

Xu XY, Ma ZP, Xia ZC, Xia LQ, Li XM, Wang LS. 2006. TIMS U-Pb Isotopic Dating Geochemical Characteristics of Paleozoic Granitic Rocks from the Middle-Western Section of Tianshan. Northwestern Geology 39:50–75 (in Chinese with English abstract)

Xu XY, Ma ZP, Xia ZC, Xia LQ, Li XM, Wang LS. 2006b. TIMS U-Pb isotopic dating and geochemical characteristics of Palaeozoic granitic rocks from the Middle-Western section of Tianshan. Northwest Geol 39(1):50–75 (in Chinese with English abstract)

Yang T N, Wang Y, Li J Y, et al. 2007. Vertical and horizontal strain partitioning of the Central Tianshan (NW China): Evience from structures and 40Ar/39Ar geochronology. J. Str. Geol., 29: 1605-1621

Yang TN, Li JY, Sun GH, Wang YB. 2006. Earlier Devonian active continental arc in Central Tianshan: evidence of geochemical analyses Zircon SHRIMP dating on mylonitized granitic rock. Acta Petrol Sin 22:41–48 (In Chinese with English abstract)

Yang TN, Li JY, Sun GH, Wang YB. 2008. Mesoproterozoic Continental Arc Type Granite in the Central Tianshan Mountains: Zircon SHRIMP U-Pb Dating and Geochemical Analyses. Acta Geologica Sinica (English Edition), 82(1): 801-809

Yang XK, Cheng HB, Ji JS, Luo GC, Tao HX. 2000. Analysis on gold and copper ore-forming setting with ore-forming system of Eastern Tianshan. Journal of Xi'an Engineering University 22, 7–14 (in Chinese with English abstract)

Yang XK, Tao HX, Luo GC, Ji JS. 1996. Basic features of plate tectonics in Eastern Tianshan of China. Xinjiang Geology 14, 221–227 (in Chinese with English abstract)

Yin A, Nie S. 1996. A Phanerozoic palinspastic reconstruction of China its neighboring regions. In: Yin A, Harrison TM (eds). Tectonic Evolution of Asia. Cambridge Univ Press, Cambridge, United Kingdom, pp 442–485

Zhai W, Sun XM, Gao J, He XP, Liang JL, Miao LC, Wu YL. 2006. SHRIMP dating of zircons from volcanic host rocks of Dahalajunshan Formation in Axi gold deposit, Xinjiang, China, its geological implications. Acta Petrol Sin 22:1399–1404 (in Chinese with English abstract)

Zhang LF, Ai YL, Li XP, Rubatto D, Song B, Williams S, Song SG, Ellis D, Liou JG. 2007a. Triassic collision of western Tianshan orogenic belt, China: Evidence from SHRIMP U-Pb dating of zircon from HP/UHP eclogitic rocks. Lithos 96:266–280

Zhou D W, Su L, Jian P, et al. 2004. Zircon U-Pb SHRIMP ages of Yushugou ophiolitic terrane in Southern Tianshan and their tectonic implications. Chinese Sci Bull, 49(13): 1415-1419

Zhou D, Graham SA, Chang EZ, Wang BY, Hacker B. 2001. Paleozoic tectonic amalgamation of the Chinese Tianshan: Evidence from a transect along the Dushanzi-Kuqa highway. In: Hendrix MS, Davis GA (eds). Paleozoic Mesozoic tectonic evolution of central Asia: from continental assembly to intracontinental deformation. Boulder, Colorado, Geol Soc of Am Mem 194: 23–46

Zhu B Q, Feng Y M, Yang J L, et al. 2002. Discovery of ophiolitic mélange and Silurian foreland basin at Gangou of Tokxun, Xinjiang and their tectonic significance. Xinjiang Geol, 20(4): 326-330 (in Chinese with English abstract)

Zhu YF, Zhang LF, Gu LB, Guo X, Zhou J. 2005. The zircon SHRIMP chronology trace element geochemistry of the Carboniferous volcanic rocks in western Tianshan Mountains. Chin Sci Bull 50:2201–2212

Zhu YF, Zhou J, Guo X. 2006. Petrology Sr-Nd isotopic geochemistry of the Carboniferous volcanic rocks in the western Tianshan Mountains, NW China. Acta Petrol Sin 22:1341–1350 (in Chinese with English abstract)

Zhu Yongfeng, Song Biao. 2006. Petrology and SHRIMP chronology mylonitized Tianger granite，Xinjiang：also about the dating on hydrothermal zircon tim in granite. Acta Petrologica Sinica, 22(1): 135-144 (in Chinese with English abstract)

Zhu Z X. 2007. The geological components and tectonic evolution of South Tianshan, Xinjiang, PhD Dissertation, Chinese Academy of Geological Sciences, Beijing, 1-210.

SCIENTIFIC PROGRAM

17 – 18 September

Day 1: Thursday 17 September

10:30 – 10:45 Opening address of Prof. Wang Boling, director of 305 Project, organizer of workwhop

10:45 – 11:00 Introduction of conference by Dr. R.X. Zhu, Academician CAS and Director of IGG, organizer of workwhop

HP Metamorphism & Geochronology

Chairman: Jahn B.M.

11:00 – 11:20 **Kroner A.**: New zircon, Sm-Nd, and Ar-Ar ages for Precambrian and Palaeozoic rocks from the Tianshan orogenic belt in Kyrgyzstan and disappearance of the Archaean

11:20 – 11:40 **Zhang Lifei**: The UHP metamorphic eclogites from western Tianshan, China

11:40 – 12:00 **Gao Jun:** Late Carboniferous instead of Triassic collision of the Yili and the Tarim blocks along the southwestern margin of the Central Asia Orogenic belt: evidence from Cameca U–Pb dating of zircon from eclogites in the western Tianshan Mountains, NW China

12:00 – 12:20 **Windley B.:** UHT eclogites (1000 degree, 20-23 Kbar) in High-grade gneisses-Archaean subduction and Proterozoic Sutures

Coffee break

Tectonics (1)

Chairman: Kroner A.

13:00 – 13:20 **Charvet J.:** Paleozoic tectonic and geodynamic evolution of Chinese Tianshan belt

13:20 – 13:40 **Xiao Wenjiao**: Paleozoic accretionary process of the Beishan orogenic collage: implication for the tectonics of southern Altaids

13:40 – 14:00 **Wilde Simon:** Termination of the eastern Central Asian Orogenic Belt due to onset of Pacific-plate accretion in the latest Triassic-Early Jurassic

14:00 – 14:20 **Lin Wei:** Paleozoic tectonics of the south-western Chinese Tianshan: New insights from a structural study of the high-pressure/low-temperature metamorphic belt

Lunch

Tectonics (2)

Chairman: Guo Zhaojie

16:00 – 16:20 **Shu Liangshu**: Studies of three Late Paleozoic strike-slip zones in the Tianshan region, NW China

16:20 – 16:40 **Natal'in Boris A.**, Permian-Triassic transcontinental shear zones in northern Asia

16:40 – 17:00 **Wang Bo:** Synkinematic calc-alkaline and alkaline magmatism in Permian transcrustal mega-shear zones: implication to the post-orogenic tectonics, western Chinese Tianshan (Central Asia)

17:00 – 17:20 **Choulet Flavien**: New paleomagnetic study of Late Paleozoic rocks of the Junggar Basin (Northwestern China) and insights for the geodynamic evolution of Central Asia

Coffee break

Magmatism and Geochemistry

Chairman: Xiao Wenjiao

17:40 – 18:00 **Jahn B.M.:** Peralkaline Granitoid Magmatism in the Mongolian-Transbaikalian Belt: Evolution, Petrogenesis and Tectonic Significance.

18:00 – 18:20 **Wang Tao:** Paleozoic magmatism in the east most Tianshan orogenic belt, NW China and its implications for tectonic evolution

18:20 – 18:40 **Jahn B.M.:** Litvinovsky - Accretionary Orogens and Growth of the Continental Crust in the Phanerozoic.

Ore deposits

Chairman: Shu Liangshu

18:40 – 19:00 **Reimar Seltmann:** Gold-copper giants of central Eurasia: isolated hot spots vs tracking metallogenic belts that formed during orogenic cycles

19:00 – 19:20 **Qin Kezhang**: Temporal-spatial distribution pattern of major ore deposits as clue and constrain on the tectonic evolution and continental growth of the Chinese Tianshan

20:00 Welcome party organized by Xinjiang Science and Technology Committee (Xinjiang Kewei)

Day 2: Friday 18 September

Mesozoic-Cenozoic evolution

Chairman: Windley

10:00 – 10:20 **Guo Zhaojien:** Mesozoic-Cenozoic relationships between Tianshan Mountain and peripheral basins: evidences from sedimentology and exhumation of Jurassic in Houxia area, Urumchi

10:20 - 10:40 **Wang Qingchen:** Differential uplift of the Chinese Tianshan since the Cretaceous: constraints from sedimentary petrography and apatite fission-track dating

Other orogenic belts

Chairman: Wang Bo

10:40 – 11:00 **Yamirka Rojas-Agramonte:** Geochemistry and SHRIMP zircon ages of granitoid rocks from the northern ophiolite mélange of central Cuba: implications for late cretaceous Caribbean geology

11:00 – 11:20 **Rosenbaum Gideon:** Subduction rollback, slab tear faults and oroclinal bending

Potential talks to be confirmed

11:20 – 11:40 Li Jinyi

Other temporay presentations or General discussion and drafting of summary

11:40 – 12:00

12:20 – 12:40

Coffee break

13:00

Lunch

16:00 General discussion and drafting of summary

19:30 Conference closing address by Dr. Qingchen Wang, Chaiman of the project TOPO Asia

20:00 Closing party organized by workshop committees

ABSTRACTS

(IN ALPHABETIC ORDER)

Paleozoic tectonic and geodynamic evolution of Chinese Tianshan belt

Charvet J.[1]**,** Shu L.S.[2], Laurent-Charvet S.[3], Wang B.[4], Faure M.[5], Cluzel D.[6], Chen Y.[7], de Jong K.[8]

[1]ISTO, Université d'Orléans, Orléans, France, jacques.charvet@univ-orleans.fr
[2]State Key Laboratory for Mineral Deposits Research, Nanjing University, Nanjing 210093, China,
[3]Institut Polytechnique LaSalle Beauvais, Département Géosciences, Beauvais, France,
[4]Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan, ROC
[5]ISTO, Université d'Orléans, Orléans, France
[6]PPME, Université de la Nouvelle Calédonie, Noumea, New Caledonia
[7]ISTO, Université d'Orléans, Orléans, France
[8]School of Earth and Environmental Sciences, Seoul National University, Seoul, Korea

Chinese Tianshan (Fig. 1) is a key area for understanding the Paleozoic accretion of the southern Central Asian Orogenic Belt (CAOB) and, subsequently, how and when took place the closure of the Central Asian Ocean in this region. During the last decade, structural studies, together with new dating, improved our knowledge of the development of this orogen (Shu et al., 2002; Laurent-Charvet et al., 2003, Charvet et al., 2007; Wang et al. 2008, de Jong et al., 2008).

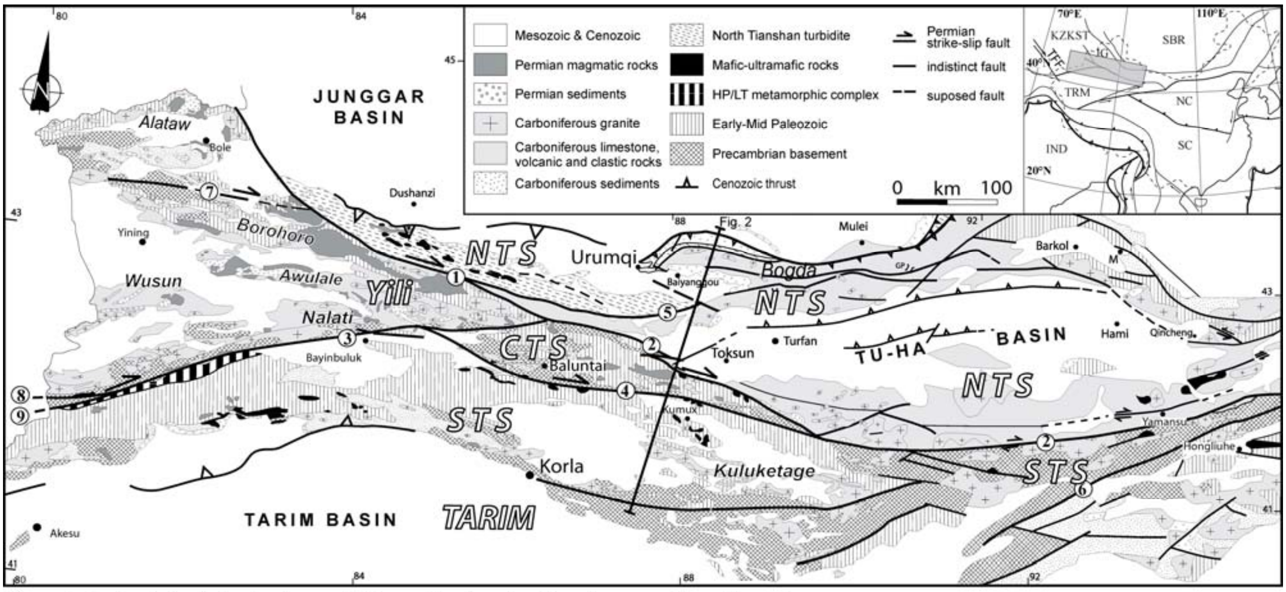


Figure 1 : Geological and structural map of Chinese Tianshan. Location of cross-section of figure 2.

The present mountain belt, due to the Indian collision, shows in cross-section three Paleozoic suture zones (Fig. 2), in chronological order: the Upper Devonian Central Tianshan Suture Zone (CTSZ), Lower Carboniferous South Tianshan Suture Zone (STSZ), and Uppermost Carboniferous-Lower Permian North Tianshan Suture Zone (NTSZ). The latter is mainly visible in the western part, on the northern side of Yili Unit. These sutures are marked by ophiolitic mélanges; CTSZ and STSZ include also HP metamorphic rocks.

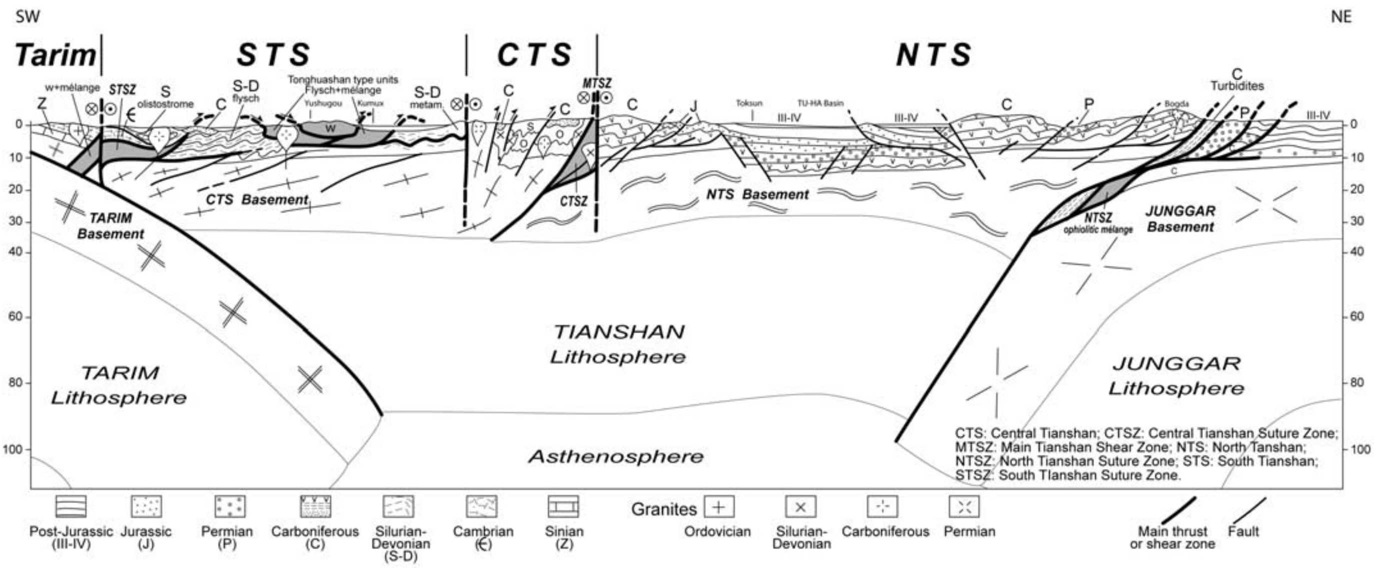


Figure 2 : Nowadays structural lithosphere scale cross-section of the Chinese Tianshan. Location on figure 1.

The Paleozoic evolution comprises two main stages (Fig. 3).

A first accretion-collision stage built the Eo-Tianshan range, before the Early Carboniferous (Visean), in which all tectonic structures verge northwards. Geodynamic evolution records Ordovician-Early Devonian southward subduction of a Central Tianshan (CTS) ocean beneath the Tarim active margin, from which a CTS island arc was detached during the Silurian-Devonian by opening of the South Tianshan (STS) back-arc basin. The closure of the CTS ocean and of the STS back-arc basin led to the CTSZ and STSZ respectively, both underlined by ophiolitic mélanges and HP metamorphic rocks. The CTSZ is often cut by the dextral strike-slip Main Tianshan Shear Zone or Nalati Fault, forming the faulted CTS northern boundary. However, in Western Tianshan, some sections exhibit the original geometry of the suture, where ocean-derived HP metamorphic units overthrust northward the basement of Yili, eastern extension of the composite Kazakhstan block. After the collision, subsequent uplift was significant with erosion of the arc root and basement.

A second accretion stage involved southward Late Devonian-Carboniferous subduction of the North Tianshan (NTS) ocean beneath the Eo-Tianshan active margin, creating the Yili-NTS magmatic arc. Late Carboniferous-Early Permian oceanic closure and collision with the Junggar block led to the North Tianshan Suture Zone (NTSZ), outlined by the Bayingou ophiolitic mélange and former accretionary wedge. This collision developed north-verging structures in Yili-NTS, and some symmetrical south-verging structures in CTS and STS.

The Late Carboniferous-Early Permian NTSZ, now partly hidden due to Cenozoic thrusting, is likely the trace of the last oceanic remnant of the Central Asian Ocean, the youngest suture of the CAOB separating Gondwana-derived from peri-Siberian units.

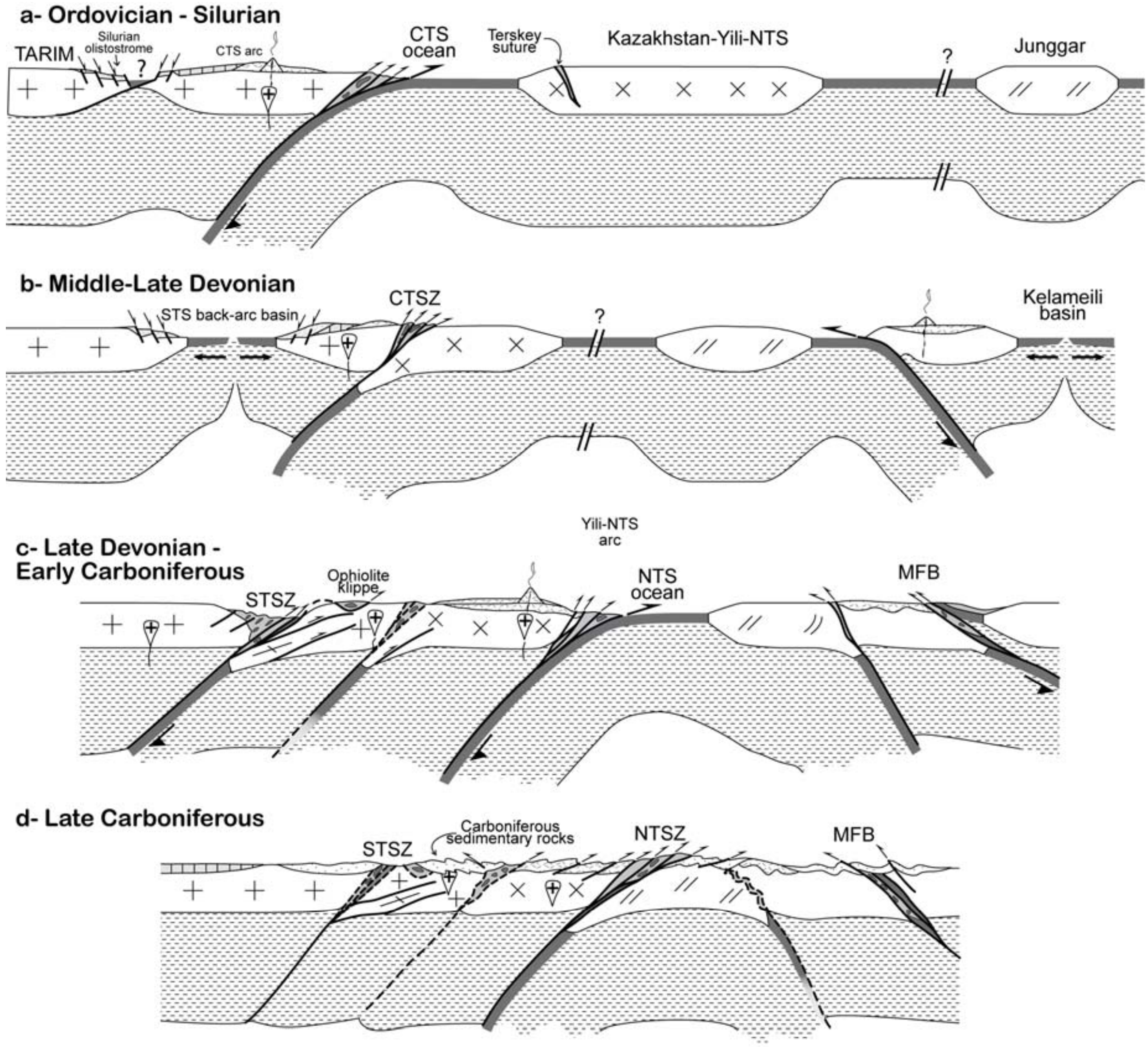


Figure 3 : Geodynamic scale model of the Chinese Tianshan between Ordovician and Late Carboniferous times.

During the Permian, all these units, already welded, experienced a major wrenching, dextral in Tianshan, sinistral in Mongolian Fold Belt to the north, accommodating an opposite motion of Tarim and Siberia indicated by paleomagnetic data. That was accompanied by pull-apart basin opening and post-tectonic magmatism expressed in volcanic rocks and plutons. The coeval emplacement of Permian calc-alkaline and alkaline suites is noteworthy in Tianshan, showing the influence of the mantle metasomatism during the Carboniferous subduction.

Deformation resumed during the Mesozoic, as documented by Triassic and Jurassic unconformities. But these tectonic events were purely intra-continental, like the Cenozoic one responding to the Asia-India collision.

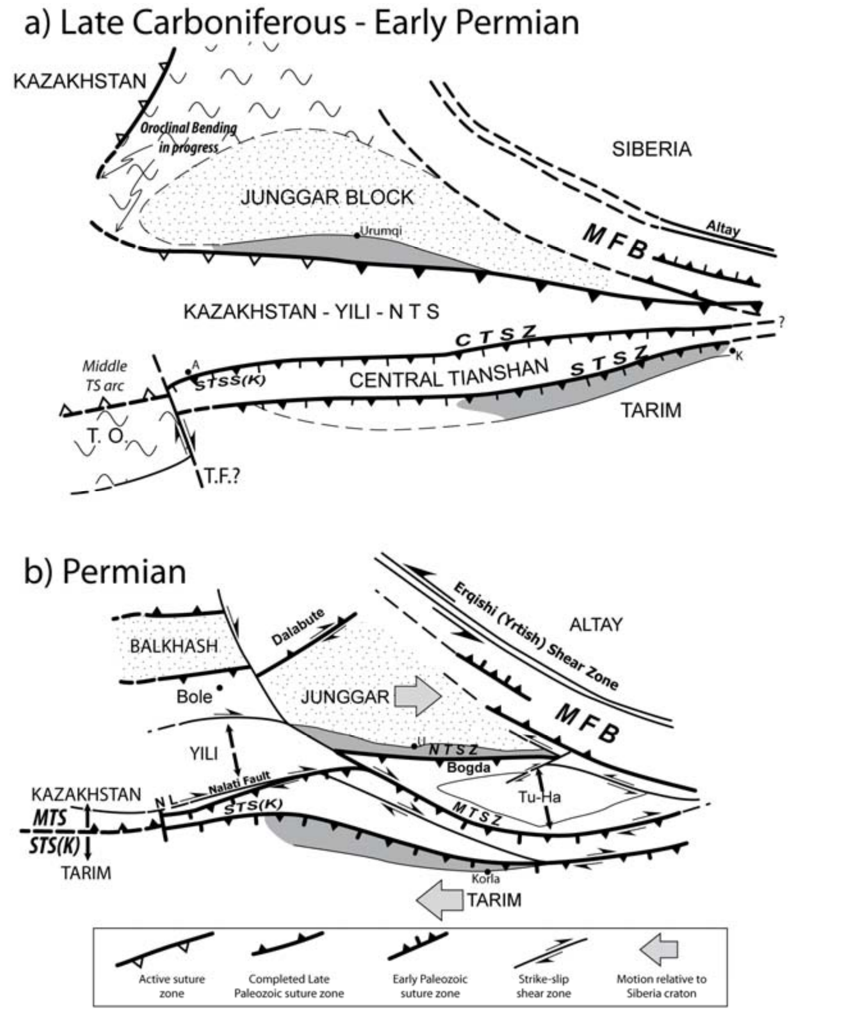


Figure 4 : Map-view cartoon showing the evolution of main units and suture zones around Junggar from Late Carboniferous to Late Permian; a) Late Carboniferous; final closure of Asian ocean along the NTSZ, by overthrusting of Yili-NTS onto the Junggar block and the southern MFB; b) Rearrangement of units due to the Permian wrenching, accompanied by opening of Yili and Tu-Ha basins.

References

Charvet J., Shu L.S., Laurent-Charvet S., 2007. Paleozoic structural and geodynamic evolution of eastern Tianshan (NW China): welding of the Tarim and Junggar plates. Episodes, 30, 162-186

de Jong K., Wang B., Faure M., Shu L.S., Cluzel D., Charvet J., Ruffert G., Chen Y., 2008. New ^{40}Ar/^{39}Ar age constraints on Late Palaezoic tectonic evolution of the western Tianshan (Xinjiang, northwestern China), with emphasis on Permian fluid ingress. Int J Earth Sci, doi 10.1007/s00531-008-0338-8

Laurent-Charvet S., Charvet J., Monié P., Shu L.S., 2003. Late Paleozoic strike-slip shear zones in eastern Central Asia (NW China): new structural and geochronological data. Tectonics, 22, 1099-1101

Shu L.S., Charvet J., Lu H.F., Laurent-Charvet S, 2002. Paleozoic accretion-collision events and kinematics of ductile deformation in the central-southern Tianshan Belt, China. Acta Geol Sinica, 76, 308-323

Wang B., Faure M., Shu L.S., Cluzel D., Chen Y., Charvet J., 2008. Paleozoic tectonic evolution of the Yili Block, Western Chinese, Tianshan: Bull Soc Géol France, 179, 483-490

New paleomagnetic study of Late Paleozoic rocks of the Junggar Basin (Northwestern China) and insights for the geodynamic evolution of Central Asia

Choulet F. [1], Y. Chen[1,2], B. Wang[3,4], M. Faure[1,2], D. Cluzel[5], W. Lin[2], J. Charvet[1] and B. Xu[6]

[1] Université d'Orléans, CNRS/INSU, Institut des Sciences de la Terre d'Orléans – UMR 6113, France
[2] Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China
[3] Department of Earth Sciences, Nanjing University, Nanjing, China
[4] Institute of Earth Sciences, Academia Sinica, Taipei
[5] Université de la Nouvelle Calédonie
[6] School of Earth and Space Sciences, Peking University, Beijing, China

The continental or oceanic nature and the geographic extent of the Junggar basement remain controversial; nevertheless this area presents special interests in order to better understand the Paleozoic tectonic framework of Central Asia. A paleomagnetic study has been performed on Late Paleozoic rocks around Junggar Basin to check if it can be regarded as a rigid block at the end of the Paleozoic. 158 sedimentary and volcano-sedimentary rock cores have been collected on 25 sites. Among them, 11 sites located in the southern border of the basin, in Bogda Shan near Urumqi, consist of Permian red sandstone, and 14 sites of Early Carboniferous grey sandstone come from the West Junggar Mountains, near Karamay. Magnetite is the main carrier for magnetic signal in this collection.

In Permian red beds of Bogda Shan area, the characteristic components of P_1 and P_2 show a solo reversed polarity and passed a positive regional fold test, the magnetization can be therefore considered as primary. Two new paleomagnetic poles have been consequently calculated for the periods of P_1 at 79.5°N, 36.6°E and of P_2 at 60.4°N, 4.7°E with a paleolatitude at ~50 and 40°N, respectively.

The Early Carboniferous sites are characterized by reverse polarity, and show a negative fold test indicating post-folding secondary magnetization. Thus, according to the spatial distribution of the sampling sites with respect to Late Carboniferous-Early Permian granitic plutons and Late Permian mafic dykes, two subgroups can be distinguished. The remagnetized sites, related to Late Carboniferous – Early Permian granite emplacement, yield a paleomagnetic pole at 65.3°N, 329.8°E, and the sites located at the vicinity of Late Permian mafic dykes present a paleomagnetic pole at 64.8°N, 179.4°E with relatively lower paleolatitudes at ~30 to 35°N, respectively.

Our paleomagnetic data from sections near Urumqi, and previous ones as well, show stationary and coherent poles for South Junggar area during the Carboniferous and Permian. These poles are close to the Present. However, paleomagnetic data from NW Junggar indicate a significant anticlockwise rotation between the Late Carboniferous-Early Permian and the Late Permian. It seems that paleolatitudes of NW Junggar rocks are similar to those of NE Kazakhstan, with meaningful differences in declination until the Late Permian, and thereafter become consistent.

Thus, the South and West Junggar areas probably experienced contrasting tectonic evolutions, and the Present Junggar Basin cannot be considered as a rigid block during the Late Paleozoic. The meaningful differences in both latitude and rotation of Late Permian poles between South and West Junggar may argue for the importance of post-Permian tectonics (e.g. Triassic to Cenozoic) in Central Asia.

Mesozoic-Cenozoic relationships between Tianshan Mountain and peripheral basins: evidences from sedimentology and exhumation of Jurassic in Houxia area, Urumchi

Guo Zhaojie, Wu Chaodong, Zhang Zhicheng

Key Laboratory of Orogenic Belts and Crustal Evolution (Peking University), Ministry of Education, Beijing 100871

The Houxia depression is now an intermountain basin near Urumchi, Xinjiang. The southern Houxia section developed alluvial fans in Badaowan Formation (J_1b) of the earlist Jurassic, while braided river was developed in the northern section, so the Houxia area was close to the south edge of the basin in the beginning of Jurassic. The ancient current directions of early to middle Jurassic in the south and north side of Houxia depression are all northward. We propose that Houxia and southern Junggar must have been joined together and constituted one basin in Jurassic, while the border between basin and mountain was close to Houxia area and differed largely from now. There exist a few intermountain depressions within Tianshan Mountain and they all have Jurassic sediments with coal-containing strata in lower to middle Jurassic. These indicate that their sedimentary environments are very similar and all developed swamps. From these facts, we can conclude that there were no high mountain in Tianshan area in Jurassic and it just was hilly. To constrain the sedimentary and exhumation history of Jurassic in Houxia area, we conducted integrated researchs on apatite fission track dating and vitrinite reflectance (Ro) of coals. The results show that the middle Jurassic coals in Houxia area should been buried at least 3 km in depth, and the apatite fission track dating records a rapid cooling event beginning at about 10 Ma, interpreted as exhumation of rocks because of the uplift of the mountains and foreland thrusting northward in Cenozoic resulting from the India-Asia collision.

Keywards: Houxia depression, Jurassic, sedimentology, apatite fission track dating, Mountain and basin relationship

Peralkaline granitoid magmatism in the Mongolian-Transbaikalian Belt: evolution, petrogenesis and implications for crustal growth

Jahn Bor-ming [1] and Boris A. Litvinovsky[2]

[1] Institute of Earth Sciences, Academia Sinica, Nangang, Taipei 11529, Taiwan

[2] Dept. of Geol. & Environ. Sci., Ben Gurion Univ. of the Negev, Beer Sheva 84105, Israel

The Central Asian Orogenic Belt (CAOB) is well-known for its massive generation of juvenile crust in the Phanerozoic. In eastern CAOB, voluminous peralkaline and alkaline (alkali-feldspar) granitoids and genetically related bimodal volcanics were emplaced in three stages from Early Permian to late Mesozoic: 295–270 Ma, 230–190 Ma and 150–120 Ma. They occur as huge granitoid belts in extensional tectonic settings and form a complex network of about 12 million km2 in area. Among them the 2500 km-long Mongolian-Transbaikalian Belt (MTB) is the most spectacular and it comprises more than 350 granite-syenite plutons and stocks, with numerous co-genetic volcanic fields. The three stages of granitoids have similar chemical compositions but show temporal variation in Nd isotopic composition. Initial $\varepsilon_{Nd}(T)$ values range from –1 to –5 for the Early Permian, 0 to +4 for the early Mesozoic, and –2 to –3.5 for the late Mesozoic granitoids. The negative $\varepsilon_{Nd}(T)$ values observed in the MTB are not typical of the CAOB granitoids, which are generally characterized by positive values. However, several pieces of evidence suggest that the MTB peralkaline and alkali feldspar granitoids were produced from enriched mantle-derived sources. The evidence includes: (1) Felsic and mafic rocks formed in the same stage have similar initial Nd-Sr isotopic ratios and Sm-Nd model ages (T_{DM}). (2) The granitoid belts extend over thousands of kilometers and intersect distinct crustal provinces, but no correlation is found in chemical compositions between the granitoids and country rocks. (3) The abundant syenites are considered to be cogenetic or, in some cases, parental to the granites. Experimental and isotope data argue for the derivation of syenites from an enriched mantle source, thus the granites (and comendites) are regarded as mantle-derived. (4) A study of melt inclusions in quartz phenocrysts of comendite indicates a high liquidus temperature of 1000–1100°C for the magma generation. This suggests that the silicic magma was generated in an unusually high temperature condition which is likely produced by basaltic magma that underplated the lower crust. The generation of voluminous peralkaline and alkaline (alkali-feldspar) granitoids and genetically related bimodal volcanic rocks represents an important addition of juvenile crustal mass to the Earth's continental crust during a time span of about 150 Ma from Late Paleozoic to Late Mesozoic.

References:

Chen and Jahn (2004) Journal of Asian Earth Sciences 23, 691-704.

Han et al. (1997) Chemical Geology 138, 135-159.

Hong et al. (1994) Journal of SE Asian Earth Sciences 10, 169–176

Hong et al. (1996) Journal of SE Asian Earth Sciences 13, 13-27.

Jahn et al. (2004) Journal of Asian Earth Sciences 23, 629–653.

Kovalenko et al. (2004) Journal of Asian Earth Sciences 23, 605-627

Leontiev et al. (1981) Nauka, Novosibirsk, 330 p

Li and Yu (1993) Geochimica 4, 389 - 398.

Shi et al (2004) Acta Geologica Sinica 78, 789 - 799.

Wang et al. (1995) Chinese Journal of Geochemistry 14, 323-335.

Wang and Zhao (1997) Geochimica 26, 24–35.
Wei et al. (2001) Acta Petrologica Sinica 17, 95–111.
Wu et al. (2002) Chemical Geology 187, 143–17
Yanshin (Ed.) (1980) Tectonics of Northern Eurasia. Nauka, Moscow, 400pp (in Russian).
Yarmolyuk (1983) Nauka, USSR, 198 pp. (in Russian).
Yarmolyuk et al. (2001) Petrology 9, 302-328.
Yarmolyuk et al. (2002) Geotectonics 36, 293-311.
Yarmolyuk et al. (2005) In: V.I. Kovalenko (Ed), Tectonic Problems of Central Asia. World of Science Publisher, Moscow, 197-226.
Zanvilevich et al. (1985) Nauka, Moscow, 231 pp

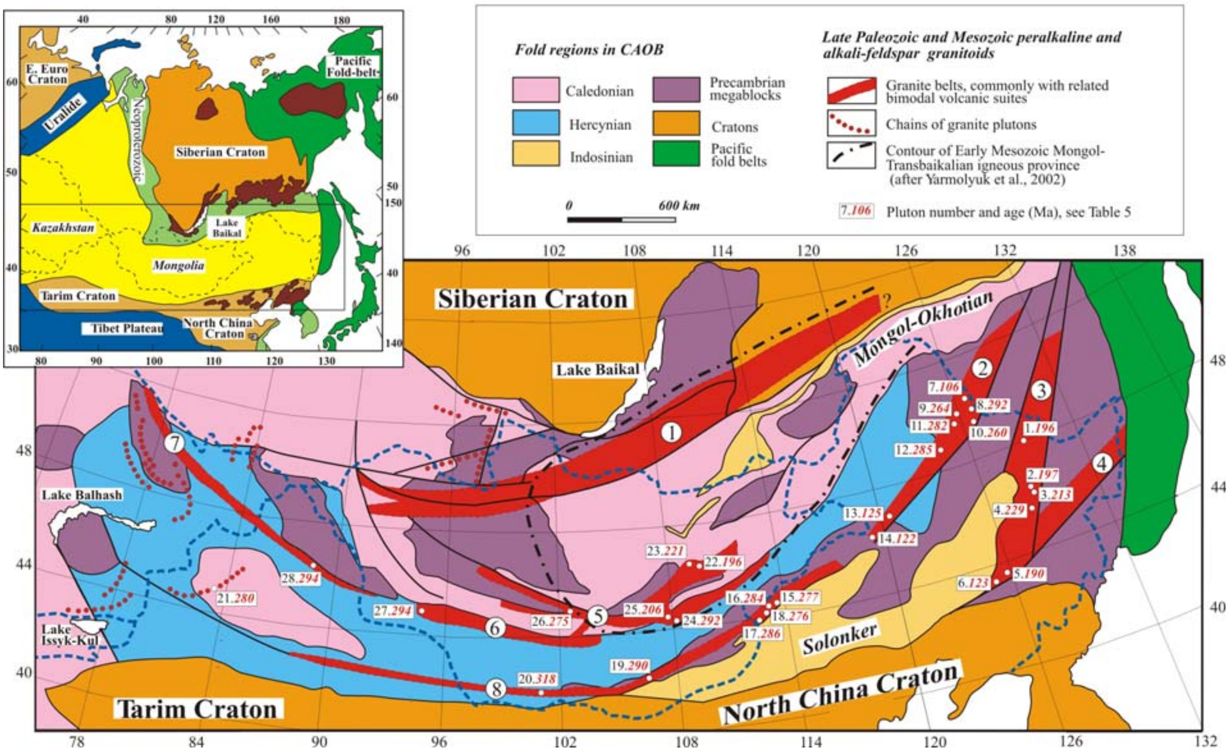


Fig. 1. Distribution of the Late Paleozoic and Mesozoic granitoid belts in the Central Asian Orogenic Belt. The map area corresponds to the rectangle of the inset map. The numbers of plutons correspond to that in Table 1 (below); ages (Ma, in red) beside numbers are also taken from this table. Granite belts: 1 = Mongolian-Transbaikalian, 2 = Great Xing'an, 3 = Zhangguangcai, 4 = Jiamusi, 5 = Gobi-Altai, 6 = Main Mongolian Lineament, 7 = Eastern Kazakhstan, 8 = Gobi-Tien Shan. Data sources: Leontiev et al. (1981); Yarmolyuk (1983); Zanvilevich et al. (1985); Geological map of Mongolia (1: 1500,000) (1989). The map of magmatic rocks of Transbaikalia, Eastern Sayan and the adjacent areas in Mongolia (1: 1500,000) was produced using the followingliterature data: Han et al. (1997), Wang et al. (1995), Hong et al. (1994, 1996), Yarmolyuk et al. (2001, 2002, 2005), Wu et al. (2002), Jahn et al. (2004), Kovalenko et al. (2004), and Yanshin (Ed.) (1980).

Table 1. Summary of Age and Nd isotope data of the Late Paleozoic and Mesozoic PA and AFS granites from the CAOB

	Pluton, locality	Rock	Age (Ma)		εNd(T)		T_{DM}-2	Reference
			Rb-Sr	U-Pb	min	max	(Ma)	
	Zhangguangcai Belt (3)							
1	Qingshui	PA granite		196 ± 4	-2.1	-0.3	1002-1139	Wu et al., 2002
2	Milim	AFS granite		197 ± 2				Wu et al., 2002
3	Maojiatun	PA granite		213 ± 2	-1.4	+0.3	969-1103	Wu et al., 2002
4	Dawangzhezii	PA granite	229 ± 12		+3.1		752	Wu et al., 2002
5	Tiangiaogang	AFS granite		190 ± 2	+2.3		781	Wu et al., 2002
6	Baishilazi	PA granite		123 ± 3	+2.0		752	Wu et al., 2002
	Great Xing'an Belt (2)							
7	Shaugmachang	AFS granite		106 ± 2	+0.1	+0.2	887-899	Wu et al., 2002
8	Daheishan	PA granite		292 ± 4	+4.2	+5.3	625-660	Wu et al., 2002
9	Guguhe	AFS granite		264 ± 5	+2.0		872	Wu et al., 2002
10	Songmushan	AFS granite		260 ± 3	+2.1		858	Wu et al., 2002
11	Sizhanlinchang	AFS granite		282 ± 4				Wu et al., 2002
12	Xiaoshantun	AFS granite		285 ± 2	+2.6		835	Wu et al., 2002
13	Nianzishan	AFS granite	125		+2.6	+2.9	683-727	Li & Yu, 1993
		AFS granite	125		+0.9	+4.3	569-728	Wei et al., 2001
14	Baerzhe	PA granite	122 ± 5		+1.9	+2.5	711-759	Wang & Zhao, 1997
	Gobi-Tien Shan Belt (8)							
15	Zhanawula		277 ± 3		+2.6	+6.2	490-744	Hong et al., 1994; 2004
16	Zuhendeleng		284 ± 2		+1.2	+6.5	520-1000	Hong et al., 1994; 2004
17	Baiynula		286 ± 3		+3.6	+5.7	520-701	Hong et al., 1994; 2004
18	Xilinhot	AFS granite		276 ± 2				Shi et al., 2004
19	Khan-Bogd	PA granite	287 ± 3	290 ± 1				Yarmolyuk et al., 2008
20	Ridge Tost, dyke	PA granite		318 ± 1		+6.5		Yarmolyuk et al., 2008
	Bimodal volcanic							
	suite, Ridges Noyon	basalt	314 ± 5		+4.4	+6.7		Yarmolyuk et al., 2008
	and Tost	comendite			+5.5	+7.4		Yarmolyuk et al., 2008
21	Karamay, W. Junggar	PA granite	280		+5.0	+5.8		Hong et al., 2004
	Gobi-Altai (5) and Main Mongolian Lineament (6) Belts							
22	Dashibalbar	comendite	195.9 ± 3.9		+1.1	+1.5	870-910	Yarmolyuk et al., 2002
	association	basalt			-1.1	-1.6		Yarmolyuk et al., 2002
		PA granite	188.7 ± 2.8*					Yarmolyuk et al., 2002
23	Bayan-Ulan	PA granite	221*					Yarmolyuk et al., 2002
24	Mandakh	PA granite		292 ± 1				Yarmolyuk et al., 2008
25	Tszarta-Khuduk	PA syenite	206					Yarmolyuk et al., 2002
		basalt			+0.8	+1.7		
		comendite			+0.1	-1.0	990-1030	
26	Bayan-Tsagan Range	PA granite		275 ± 5				Yarmolyuk et al., 2005
27	Boom	AFS granite		294 ± 5				Yarmolyuk et al., 2008
	Junggar-Eastern Kazakhstan Belt (7)							
28	Kamste	AFS granite	294 ± 4		+5.2	+7.1	480-620	Chen & Jahn, 2004
	Sawudegeer	PA granite	303 ± 26		+5.6	+6.5	501-702	Han et al., 1997
	Saertielieke	PA granite	290 ± 27		+5.1	+5.6	692-1003	Han et al., 1997
	Jierdekala	PA granite	304 ± 32		+6.1	+6.7	523-557	Han et al., 1997
	South-Tasigake	PA granite	308 ± 14		+5.1	+5.5	570-878	Han et al., 1997

Numbers of belts and plutons as in Fig. 1.

* = $^{39}Ar/^{40}Ar$ data in amphibole

New zircon, Sm-Nd, and Ar-Ar ages for Precambrian and Palaeozoic rocks from the Tianshan orogenic belt in Kyrgyzstan and disappearance of the Archaean

Kröner, A.[1], Alexeiev, D.V.[2], Hegner, E[3], Corsini, M.[4], Mikolaichuk, A.[5], Xia, X.[6], Zack, T.[1], Windley, B.F.[7], Sun, M.[6], Rojas-Agramonte, Y.[1], Liu, D.[8]

[1]Institut für Geowissenschaften, Universität Mainz, 55099 Mainz, Germany, and SHRIMP Centre, CAGS, 26 Baiwanzhuang Road, 100037 Beijing, China kroener@mail.uni-mainz.de
[2]Geological Institute, Russian Acad. of Sciences, 7 Pyzhevsky per., 119017 Moscow, Russia
[3]Department für Geo- und Umweltwissenschaften, Munich University, Germany
[4]Géosciences Azur, UMR 6526, Université de Nice Sophia-Antipolis, Nice, France
[5]CAIAG, 73/2 Timur Frunze St., 720027 Bishkek, Kyrgyz Republic
[6]Deptartment of Earth Sciences, University of Hong Kong, Pukfalam Road, Hong Kong, China
[7]Department of Geology, University of Leicester, Leicester LE1 7RH, U.K.
[8]SHRIMP Centre, CAGS, 26 Baiwanzhuang Road, 100037 Beijing, China.

The Tianshan Mountain Range is part of the Central Asian Orogenic Belt and evolved through accretion-collision processes in the Neoproterozoic to late Palaeozoic. It consists of arc terranes, accretionary complexes, forearc and backarc basin assemblages as well as Precambrian microcontinental fragments, locally separated by ophiolite-decorated sutures. Using SHRIMP and LA-ICP-MS techniques we undertook single zircon reconnaissance dating of several magmatic and metamorphic units as well as sedimentary rocks in the Tianshan of Kyrgyzstan. We also report a Sm-Nd isochron and Ar-Ar phengite ages for a HP eclogite from the Atbashi mélange.

Four granitoid gneisses from the Aktyz and Chon-Kemin areas of the North Tianshan, previously interpreted as Archaean, yielded surprisingly young Neoproterozoic ages of 810-844 Ma with no evidence of older inheritance, whereas the Koch-Korka granitic gneiss has an age of 1153±4 Ma, which is in good agreement with previous results. A tuff on the Kokomeren River, where only Proterozoic rocks were reported so far, was dated at 511±4 Ma and has some Palaeoproterozoic inheritance. Well-grouped detrital zircons from a turbidite at Dolon Pass suggest derivation from a mid-late Ordovician volcanic arc in the North Tianshan. A strongly deformed granitic gneiss near the Chinese border in the upper Bayankol River, previously considered as Archaean, has an early Carboniferous age of 336±3 Ma, correlating well with granitoids in the western Chinese Tianshan. A Neoproterozoic rhyolite on the Naryn River in the Mid-Tianshan, east of Naryn town, yielded an emplacement age of 764±4 Ma. A dacite clast from a Vendian diamictite from the same area was dated at 836±4 Ma, whereas detrital zircons in the diamictite matrix range from 620 to 2400 Ma, suggesting correlation with the global Marinoan glaciation. An Ordovician clastic sediment from Moldotau Ridge on the Naryn-Bishkek road yielded Pan-African (~770 Ma) and Grenvillian (~900-1100 Ma) zircons as well as 2500-2600 Ma grains. A metarhyolite from the Karasu River, Middle Tianshan, east of the Bozbutau Mountains, NE Ferghana basin, has a late Ordovician age of 445±4 Ma. A deformed ophiolite gabbro-diorite from the South Tianshan suture zone, northern slope of Atbashe Ridge, yielded an emplacement age of 436±3 Ma, whereas a siliceous chlorite schist in the Tash Rabat Valley has an age of 465±5 Ma. A paragneiss from the Atbashe metamorphic complex at Tash Rabat yielded detrital zircon ages of 420 to 2600 Ma and a possible metamorphic overprint at ca. 320 Ma. We have been unable to obtain a zircon age for the Atbashe eclogite, but Sm-Nd mineral/whole-rock dating yielded a precise isochron age of 319.2 ± 4.3 Ma and an Ar/Ar phengite cooling age of 314-±3 Ma. The Atbashe HP mélange is overlain, unconformably, by an unmetamorphosed uppermost Carbonifers conglomerate, so accretion/ collision and uplift was completed prior to ca. 310 Ma. A metagreywacke in the HP belt south of Atbashe has detrital zircons ranging in age between 420 and 2700 Ma.

Discrepancies of our data with previously published, much older, ages in the Aktyuz and Kemin complexes may be due to mixed zircon populations in multigrain samples. The detrital age pattern and xenocrystic ages in igneous rocks in the Northern and Middle Tianshan, in particular the occurrence of Grenville-age zircon populations point to a similarity with Tarim, and this implies that Precambrian microcontinents in the Northern and Middle Tian Shan of Kyrgyzstan may be derived from the Tarim craton.

Our recent fieldwork in the Northern Tianshan of Kyrgyzstan shows the eclogitic mafic rocks at Aktyuz and Makbal to be derived from undated gabbroic dyke swarms emplaced into granitic gneisses and metasediments, and not from ophiolitic precursors. There are as yet no proven Archaean or Palaeoproterozoic rocks in the Tianshan of Kyrgyzstan.

Devonian-Carboniferous tectonic evolutional framework of the Chinese southwestern Tianshan: constraints from depositional records

Li Zhong[a] and Guocan Wang[b]
[a] *Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China*
[b] *China University of Geosciences, Wuhan, China*

The Chinese southern Tianshan is a key window for understand the late Paleozoic tectonic evolution of the southern boundary of Eurasia. However, for this key area, varied tectonic cognitions have been published in the past researches according to structural, petrological, geochemical and paleontologic data, in which not much work were from depositional data. Based on the Devonian-Carboniferous depositional records of the Chinese southwestern Tianshan, combined with petrological geochemical and dtrital zircon geochronological records, it is indicated that continential volcanic island arc once occurred and, as a provenance area, provided dtrital materials to the northern Tarim basin in the early-middle Devonian. In addition, the Carboniferous depositional records of the Chinese southwestern Tianshan probably reflected a evolutional sequence of back-arc foreland basin. The above works may further show that a tectonic transformation from passive continential margin (?) to active continential margin had finished during Late Silurian-Early Devonian, and the “Late Paleozoic South Tianshan Ocean” probably had closed before the Late Carboniferous. The study on detrital depositional records and their tectonic attributes give a primary framework for the Late Paleozoic basin prototypes and distribution in the Chinese southwestern Tianshan, which is of important significances for further discussing and understanding tectonic relationships between the “Late Paleozoic South Tianshan Ocean” and the Tethys/Paleoasia oceans.

Paleozoic tectonics of the south-western Chinese Tianshan: New insights from a structural study of the high-pressure/low-temperature metamorphic belt

Lin Wei, Michel Faure, Yonghong Shi, Qingchen Wang, Zhong Li

The south-western Chinese Tianshan orogenic belt is famous for its omphacite-bearing blueschists and associated eclogite-facies metavolcanic rocks. Although numerous petrologic, geochemical and geochronological studies are available, structural data and interpretations are still rare. This paper provides new structural data, including bulk geometry of structures and kinematic analyses, based on field and laboratory studies along the Akyazhi, Keburt and Muzaert Rivers. The study area is divided into three tectonic units, namely 1) a Southern Unit composed of weakly metamorphosed sedimentary rocks of Silurian age; 2) a Central HP/LT Unit composed of blueschist-eclogite-facies metamorphic rocks derived from basalts, pelites and volcaniclastic rocks; 3) a Northern Unit, which consists of a Carboniferous magmatic arc developed upon an amphibolite-facies metamorphic continental basement. Our structural analysis documents a polyphase deformation. The main event (D_1) is reflected by Devonian to Carboniferous top-to-the northwest ductile shearing, coeval with HP/LT metamorphism. This is followed by north-directed thrusting (D_2) of the Southern Unit over the Central HP/LT Unit, coeval with retrogression of the high-pressure rocks. A top-to-the-S (SE) deformation (D_3) overprints the earliest events and is observed in the Northern and Central Units. Lastly, Permian dextral ductile-brittle wrenching (D_4) overprints the older flat-lying fabrics. D_4 is conspicuous along the Nalati Fault that separates the Northern Unit from the Central HP/LT Unit. The absolute timing of these deformation events is discussed in the light of available radiometric dating. Our new U-Pb dating of rutile indicates that the age of peak of eclogite facies metamorphism is about 317 ± 10Ma. The structural, metamorphic and geochronological data are integrated into a geodynamic model of the south-western Chinese Tianshan that emphasizes south-directed subduction of microcontinents located between Tarim and Junggar.

GEOCHEMISTRY AND SHRIMP ZIRCON AGES OF GRANITOID ROCKS FROM THE NORTHERN OPHIOLITE MÉLANGE OF CENTRAL CUBA: IMPLICATIONS FOR LATE CRETACEOUS CARIBBEAN GEOLOGY

Rojas-Agramonte Y. (1,2,3); A. Kröner(1,2); A. García-Casco(4); T. Kemp (5); M. Pérez(6); A. Fonseca-Montero(6); Dunyi Liu(2)

(1) Department of Geosciences, University of Mainz, 55099 Mainz, Germany,

(2) SHRIMP Centre, Chinese Academy of Geological Sciences, 26 Baiwanzhuang Road Beijing 100037, China

(3) Departamento de Geología, Instituto Superior Minero Metalúrgico de Moa, Las Coloradas, Moa, Holguín, Cuba·

(4) Departamento de Mineralogia y Petrología, Instituto Andaluz de Ciencias de la Tierra, Fuentenueva s/n, Universidad de Granada – CSIC, 18002 Granada, Spain.

(5) School of Earth and Environmental Science, James Cook University, Townsville, QLD 4811, Australia.

(6) Instituto Superior Politécnico José Antonio Echeverria, Avenida 114 No 11901 entre 119 y 127 , Marianao, codigo postal 19390, Habana , Cuba.

The northern ophiolite belt (NOB) of Central Cuba consists of a mélange containing blocks of eclogite, garnet-amphibolite, amphibolitite, blueschist, greenschist, quartzite, metapelite, antigoritite and various types of intrusive rocks. Many of the granitoid varieties were interpreted as oceanic plagiogranites. We report SHRIMP U-Pb zircon ages and geochemical data for 8 unfoliated granitoid samples from the NOB in central Cuba. These samples were taken from blocks within serpentinite mélanges or intrude gabbro and diabase of the ophiolitic sequence. On the Geological Map of Cuba such rocks appear as elongated bodies with a main ESE-WNW trend, concordant with the foliation of the ophiolites. Chemically, these rocks are characterized by high SiO2 (63.6 to 74.3) and low to medium K2O (K2O = 0.21 - 2.54), and the Al-and Rb-contents are somewhat higher than in typical oceanic plagiogranites (Al2O3 = 14.15–16.32, Rb = 7.5 - 40.4 %); only two samples show a low Rb-content of 2.7 - 4.8 %. The Na2O, CaO and total iron contents range from 4.56-8.83, 0.58-3.23, and 2.77-4.27 respectively. The Rb vs (Y+Nb) diagram shows these granitoids to have volcanic arc affinity, and the AFM diagram reveals a calc-alkaline trend. Most samples have a metaluminous character with molecular ratio (mol. A/NK) between 1 and 2, whereas three samples have a peraluminous character. A trace element variation diagram normalized to Ocean-Ridge Granite (ORG) shows enrichment in highly incompatible elements, negative Nb anomalies and depletion in heavy REE, more typical of arc-related granitoids than oceanic plagiogranites.

A sample of trondhjemite from the the Cerro el Chivo area, S of Santa Clara, provided a concordant zircon age of ~86 Ma, whereas a granodiorite and trondhjemite from the Las Bocas body, N of Placetas, yielded ages of ~75 Ma. Two peraluminous trondhjemitic samples taken from the Tres Guanos area S of Perea yielded zircon crystallization ages of ~72 and ~74 Ma. Rare Neoproterozoic and Permian inherited zircons are also present in these samples. Hf isotope ratios were obtained for five of the dated zircons, from the Tres Guanos samples. The three younger zircons, with ages of ~72 and ~74 Ma, show derivation from a depleted source region as can be expected for arc granitoids as well as the oldest xenocryst (~536 Ma) which is less depleted but still from a juvenile Pan-African source. The younger xenocryst (~268 Ma) have negative $\varepsilon_{\mathrm{Hf}(T)}$ value (-2.35), implying that the zircon derived from a continental source.

These data constraint current geotectonic models for the region, because they indicate that emplacement of the ophiolite mélange must be younger than 72 Ma. Based on current geodynamic models for the region, our data suggest that the oceanic crust in the northern ophiolite belt is of supra-subduction type and is related to a volcanic arc domain during the late Cretaceous similar, perhaps to the tectonic setting of the Coast Range ophiolite in California. Therefore would represent fragments of the Caribbean plate and not the Proto-Caribbean lithosphere. Integration of geological data of the region suggests a fore-arc position. The occurrence of inherited zircons in two peraluminous samples may imply the involvement of subducted sediments containing an ancient zircon component because in some cases inherited zircons can survive in cool and dry peraluminous melts due to the low Zr saturation level in such magmas.

Subduction rollback, slab tear faults and oroclinal bending

Rosenbaum Gideon

School of Earth Sciences, The University of Queensland, Brisbane, QLD 4072, Australia.

Most subducting slabs are gravitationally unstable and are therefore retreating relative to the overriding plate. This behaviour plays a crucial role in the development arcuate subduction zones as demonstrated by a large number of numerical and analogue experiments (e.g. Schellart and Lister, 2004; Morra et al., 2006). In this presentation, I will focus on the tectonic response to subduction anomalies in a retreating subduction system, highlighting the genetic link between subduction rollback, the development of lithospheric-scale tear faults and the formation of oroclines.

The arrival of aseismic ridges or continental terranes at the subduction zone is responsible for dramatic changes in the dynamics and kinematics of the whole subduction system. Such anomalies would locally increase the lithospheric buoyancy of the downgoing plate, thus flattening the dip of the subducting slab (Gutscher et al., 2000), modifying the structural and magmatic evolution of the overriding plate, and terminating arc volcanism (Nur and Ben-Avraham, 1981; Rosenbaum et al., 2005). Moreover, the geometry of the whole subduction system is likely to be modified by a local decrease in rollback velocities at the area of ridge subduction. In retreating plate boundaries, this results in a progressive deformation of the subducted slab and the development of cusps (e.g. Aleutian–Kamchatka junction).

The effect of local collisional events on the evolution of a subduction system is well manifested in the Alpine-Mediterranean subduction-collision system. The current morphology of this orogenic belt, from Gibraltar to the Aegean Sea, comprises of a series of oroclines. Their formation is attributed to interactions between subduction rollback and local collisional events (Rosenbaum and Lister, 2004a). In Italy, the incorporation of continental material at the subduction zone resulted in variations in rollback velocities along the strike of the subduction zone (Rosenbaum and Lister, 2004b). The process involved tearing and segmentation of the subducting lithospheric slab (Royden et al., 1987; Rosenbaum et al., 2008). Such deep (100-500 km) sub-vertical tear faults are recognised in seismic tomography results (Rosenbaum et al., 2008) and their development is consistent with the tectono-magmatic history of the region.

In conclusion, subduction of anomalies is responsible for pronounced effects on the subduction zone, including the formation of subduction curvature and the development of orogen-perpendicular lithospheric tear faults and associated magmatism. The existence of these features can potentially unravel the location and timing of ancient subduction anomalies in complex convergent boundary zones, such as the Paleozoic Central Asian orogenic belt.

GUTSCHER, M.-A., SPAKMAN, W., BIJWAARD, H. & ENGDAHL, E.R., 2000. Tectonics, 19(5): 814-833.

MORRA, G., K. REGENAUER-LIEB, & D. GIARDINI (2006), *Geology*, *34*, 877-880.

NUR, A. & BEN-AVRAHAM, Z., 1981. In: L.D. Kulm, J. Dymond, E.J. Dasch, D.M. Hussong and R. Roderick (Editors), Nazca Plate: crustal formation and Andean convergence. Geological Society of America Memoir, pp. 729-740.

ROSENBAUM, G., GASPARON, M., LUCENTE, F.P., PECCERILLO, A. & MILLER, M.S., 2008. Tectonics, 27: TC2008, doi:10.1029/2007TC002143.

ROSENBAUM, G., GILES, D., SAXON, M., BETTS, P.G., WEINBERG, R. & DUBOZ, C., 2005. Earth and Planetary Science Letters, 239: 18-32.

ROSENBAUM, G. & LISTER, G.S., 2004a. In: A.J. Sussman and A.B. Weil (Editors), Orogenic curvature: Integrating paleomagnetic and structural analyses. Geological Society of America Special Paper, pp. 41-56.

ROSENBAUM, G. & LISTER, G.S., 2004b. Tectonics, 23(1): TC1013, doi:10.1029/2003TC001518.

ROYDEN, L., PATACCA, E. & SCANDONE, P., 1987. Geology, 15: 714-717.

SCHELLART, W. P., & LISTER, G. S. 2004, In: A.J. Sussman and A.B. Weil (Editors), Orogenic curvature: Integrating paleomagnetic and structural analyses. Geological Society of America Special Paper, pp. 237-258

Southwestern Tianshan: A structural analysis and its complications for the geodynamic evolution

Scheltens Mark [1,2] and LiFei Zhang [2]
1Faculty of Geosciences, Utrecht University, The Netherlands
2School of Earth and Space Sciences, Peking University, Beijing 100871, China

The Tianshan Mountains in NW China are part of the Central Asian Orogenic Belt, extending over 2500 km from Uzbekistan to Xinjiang Province in NW China. In the early 2000's Chinese Tianshan was recognized as a UHP belt, however, it is only recently proven that it indeed is a UHP terrane by the observation of coesite inclusions within garnet of the southwestern Tianshan eclogites. Several fault systems exist within the Chinese Tianshan area, from which the Main Tianshan Suture Zone (MTSZ) – that splits into the North Central and South Central Tianshan Sutures (NCTS and SCTS) just west of the city of Urumqi – is most important. Some controversies about the motions along the shear zones in Tianshan still exist; the direction of the motion, significance of the motions along the faults and whether motion occurred syn-orogenic or post-orogenic. A question arises along the SCTS, whether motion was right-lateral or left-lateral. This shear zone is very important for the understanding of the evolution of the Yili block. Two views exist for this part of the evolution of Tianshan: (1) Indentation of the Yili block in between the Junggar and Tarim blocks, (2) dragging of the Yili block into its place by the clockwise rotation of the Tarim block. The geodynamic setting is also not completely understood and two main views have been proposed: (1) southward subduction, where Central Tianshan Ocean subducts beneath the Tarim plate, and (2) northward subduction, where the South Tianshan Ocean subducts beneath the Yili block. This summer's fieldwork and research will aim to get an answer to these questions. Two roughly north-south cross-sections will be analyzed along the Muzhaerte river and the Kapuerte river, which run from the granulites to the north of the UHP block, through the SCTS, the UHP block and the Haerkeshan fault to the south of the UHP block. The two fault zones bordering the UHP block to the north and the south will be analyzed in great detail, in order to get a comprehensive view on the evolution of the fault zones and their past senses of motion. Absolute age-dating will be performed on the greenschist rocks, the SCTS mylonites and Haerkeshan fault rocks using Rb/Sr and Sm/Nd dating techniques. This will hopefully result in an exhumation rate of the UHP rocks. Beside this, PTt paths will be constructed for each of the rock units. These data will hopefully give a better insight of the processes that played a role during exhumation of the UHP rocks and about the geodynamic evolution of Western Tianshan. All these data will be combined to be able to construct a tectono-metamorphic reconstruction of the Western Tianshan area. Ultimately, all data for Western Tianshan will be compared with data from Eastern Tianshan obtained by other studies to be able to propose a new (or adjusted) geodynamic evolution model of the Chinese Tianshan area.

Gold-copper giants of central Eurasia: isolated hot spots vs tracking metallogenic belts that formed during orogenic cycles

Seltmann Reimar & Alla Dolgopolova

Centre for Russian and Central EurAsian Mineral Studies (CERCAMS), Department of Mineralogy, Natural History Museum, Cromwell Road, London SW7 5BD, UK

Over the last decade the term “orogenic gold deposits” has entered the literature on metallogenesis in the context of geodynamic reconstruction. However, this term has tended to place a unilateral focus on crustal processes, despite the dilemma that such a broad concept is also compatible with “non-orogenic” (mantle-triggered) mass-and-heat-transfer processes that are related to accretion and subduction processes. Interdisciplinary studies recently undertaken by the CERCAMS team in the Central Asian Orogenic System (CAOS) and the ongoing debate over such terminology call for a paradigm change to balance the understanding of the complex metallogenic processes involved. Magmatic arc rocks of the Tienshan mountain belt show Sr-Nd-Pb-Hf isotope patterns that are indicative of a significant juvenile (mantle) input. Isotope geochemistry of ores (Os and noble gas isotope data), petrological features (mantle xenoliths), and tectonic and geophysical evidence (zones of seismic transparency) from giant ore deposits in the CAOS, all showing mantle involvement, require a systematic and integrated assessment of the data. The novel contribution of the research has shed light on the processes that led to the formation of giant ore deposits in different settings of the CAOS, hinting on the role of “hot spots” that superimpose the crustal architecture that was initially formed by the subduction magmatism of the orogenic belts.

The research focused on the geological and isotope systematics in four Cu-Au giants from different geological settings of the CAOS (Figure 1). The selected sites include three deposits in Uzbekistan: i) the Kalmakyr porphyry copper-gold deposit in continental arc setting, Kurama, Middle Tienshan (~315 Ma SHRIMP U-Pb zircon age - Seltmann & Porter 2005, and ~313 Ma Re-Os molybdenite age - pers. comm. R. Creaser), ii) the Zarmitan intrusion-related gold deposit, Nuratau (~283 Ma SHRIMP U-Pb zircon age – unpublished CERCAMS data), and iii) the Muruntau metasediment-hosted lode gold deposit (~287 Ma Re-Os arsenopyrite age - Morelli et al., 2007, and ~290 Ma SHRIMP U-Pb age of Murun granite, Kyzylkum – Kempe et al., 1994). The latter two sites are located in the passive continental margin of the South Tienshan in post-collisional settings, thus in the literature classified as orogenic gold deposits (Groves et al., 1998). For comparison, the Oyu Tolgoi porphyry Cu-Au deposit (~372 Ma Re-Os molybdenite age - Kirwin et al., 2005, matching unpublished CERCAMS SHRIMP U-Pb zircon ages) has been included in the study. It represents an island arc setting (South Gobi, Mongolia). Compared to SHRIMP U-Pb zircon crystallization ages obtained for the host intrusions, available Re-Os mineralization ages are slightly younger or overlap within the analytical errors. Consequently, at all four sites the ore mineralization is spatially and temporally linked to peak magmatism. This is suggesting a continuum which would encompass porphyry-epithermal deposits at epizonal levels, passing down to lode and stockwork deposits at mesozonal depths (i.e. orogenic-style Au). A moderate mantle input is common to both these porphyry and intrusion-controlled “orogenic” deposits (Seltmann & Porter, 2005). In post-collisional “orogenic” settings established during and even after collapse rather than buildup of the orogeny, the purely crustal origin of the “orogenic ore deposits” may well be questioned.

The ongoing research has already proven that a direct contribution from the mantle is involved in the formation of deposits included in this study. This can be further consolidated via the following objectives: 1) to investigate the relative contribution of crustal and mantle sources to subduction, post-collisional and within-plate magmatic systems of the CAOS; 2) to assess the contribution of the mantle in the formation of giant ore deposits and implications for exploration; 3) to establish the relative importance of subduction vs. intraplate lithospheric mantle processes; 4) to supplement existing data on isotope mapping of magmatic arc rocks and zircons by diagnostic new isotope data (He, Ne, Ar) from sulphides (molybdenite, arsenopyrite, pyrite, chalcopyrite, galena) in the related deposits.

The development of a more comprehensive geological model for the formation of, and exploration for a number of ore deposits types is pivotal. At the moment input from the mantle is largely ignored in conventionally accepted models of 'orogenic' deposits. The identification of a significant mantle component in the formation of giant deposits will enable more effective prediction for the mining industry of exploration targets in similar geological settings. This will potentially lead to discoveries of new world-class ore deposits.

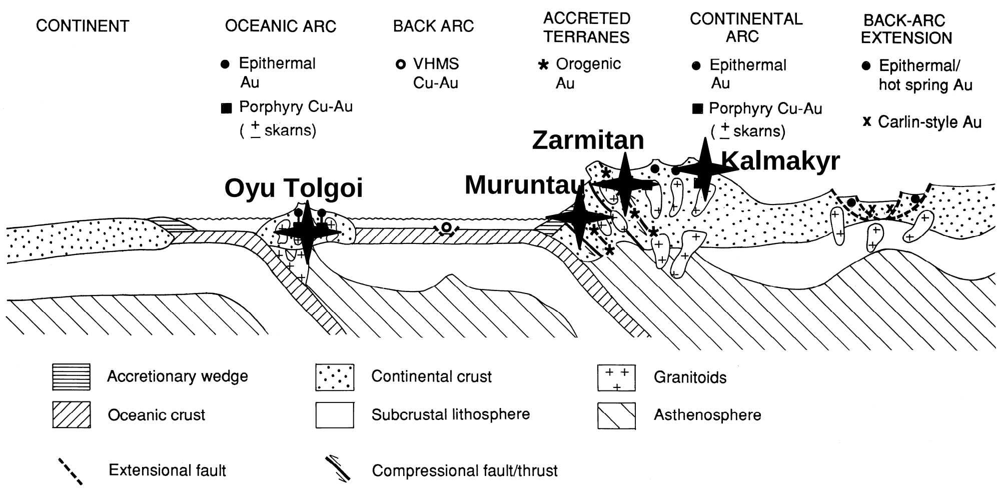


Figure 1. Tectonic setting of gold-rich mineral deposits (modified after *Groves et al., 1998*) and schematic location of the four case study sites.

REFERENCES

Groves, D.I., Goldfarb, R.J., Gebre-Mariam, M., Hagemann, S.G. and Robert, F. (1998). Orogenic gold deposits: A proposed classification in the context of their crustal distribution and relationship to other gold deposit types. *Ore Geology Reviews*, 13: 7-27.

Kempe, U., Seltmann, R., Graupner, T., Wall, V.J., Matukov, D. and Sergeev, S. (2004). SHRIMP U-Pb zircon dating of Hercynian granite magmatism in the Muruntau gold district (Uzbekistan). In Khanchuk et al. (Eds): *Proceedings Interim IAGOD Conference*, Vladivostok, Russia, p. 210–213.

Kirwin, D.J., Forster, C.N., Kavalieris, I., Crane, D., Orssich, C., Panther, C., Garamjav, D., Munkhbat, T.O. and Niislelkhuu, G. (2005). The Oyu Tolgoi Copper-Gold Porphyry Deposits, South Gobi, Mongolia; *in* Seltmann, R., Gerel, O. and Kirwin, D.J., (Eds.), *Geodynamics and Metallogeny of Mongolia with a Special Emphasis on Copper and*

Gold Deposits. IAGOD Guidebook Series 11: CERCAMS/NHM, London. pp. 155-168.

Morelli, R., Creaser, R.A., Seltmann, R., Stuart, F.M., Selby, D. and Graupner, T. (2007). Age and source constraints for the giant Muruntau gold deposit, Uzbekistan, from coupled Re-Os-He isotopes in arsenopyrite. *Geology* 35(9): 795–798.

Seltmann, R. and Porter, T.M. (2005). The Porphyry Cu-Au/Mo Deposits of Central Eurasia: 1. Tectonic, Geologic & Metallogenic Setting and Significant Deposits. In Porter T M (Ed.) *Super Porphyry Copper & Gold Deposits: A Global Perspective*. PGC Publ., Adelaide, 2: 467-512.

Studies of three Late Paleozoic strike-slip zones in the Tianshan region, NW China

Shu Liangshu[1], Charvet Jacques[2], Wang Bo[1], Faure Michel[2]
1, State Key Laboratory for Mineral Deposits Research, Department of Earth Sciences, Nanjing University, Nanjing 210093, China;
2, Institut des Sciences de la Terre d'Orleans, Université d'Orleans, 45067 Orleans, France

Following Late Paleozoic collisional orogeny, a post-collisional tectonic-magma event took place in Central Asian region to cause the termination of Tianshan Belt, which is chiefly characterized by rifting, strike-slip shearing and magmatism during the period of 290-245 Ma (Windley et al., 1990; Allen et al., 1992, 1995; Sengor et al., 1993; Natal'in et al., 1994, 2005; Charvet et al., 2001; Laurent-Charvet et al., 2002, 2003; Shu et al., 1996, 1999; 2002; Ma et al., 1997; Li et al., 2003; Zhu et al., 2004; Wang et al., 2007). The rifting activity was associated with bimodal volcanism and collapse tectonics, the strike-slip shearing yielded mylonitic zones. Rift zone and strike-slip shear zone are mainly distributed in the piedmont region. Post-collisional magmatism caused granitic intruding and basaltic underplating, the latter yielded the crowed basic inclusions and basic dykes in granitic bodies.

In Tianshan belt, thrusts and shear zones due to Paleozoic accretional events were reworked by sub-E-W ductile strike-slip faults during Late Paleozoic-Early Mesozoic time. In the seven large-scale ductile thrust faults even whole Tiangshan Belt, ductile strike-slip re-working is very common. Three large-scale ductile strike-slip shear zones are identified, namely the Nalati-Bindaban-Weiya zone along the northern margin of the Centra Tianshan, the Kanguer-Huangshan zone along the southern margin of the Turpan-Hami basin and the Erqishi-Irtysh zone in the northern part of Xinjiang and in Kazakhstan.

1. Geometric feature

The Nalati-Bindaban-Weiya ductile strike-slip shear zone, extending sub-E-W over 1500 km in China, separates the Central Tianshan belt to the south from the northern Tianshan belt to the north. It consists of an ophiolitic melange sub-zone in the southern part and a ductile strike-slip shear sub-zone in the northern part; The former is occupied by fault-bounded ophiolitic blocks with various size ranging from 200 m to 10 m, and the latter is composed of Ordovician greenschist facies metamorphic volcanic series and Silurian turbidite. Thus the Nalati-Bindaban-Weiya zone was interpreted as an accretion-collision suture of continental blocks during Paleozoic time. A complete ophiolite sequence of mantle peridotite, cumulate, diabase, basalt, flysch and chert is preserved only at Mishigou and Gangou of Toksun County. Flattened-elongated-type mica-schist, gneiss, orthogneiss and basic granulite blocks of Proterozoic basement are involved in this zone, which are strongly mylonitized.

The Kanguer-Huangshan ductile strike-slip shear zone extending E-W over 600-km long and 2~3-km wide, comprises Carboniferous volcanic rocks (basalt-andesite) and greywacke, containing Alaskan-type cumulate ultramafic-mafic-chert-marble blocks that formed a Late Carboniferous suture. Enormous Cu-Ni-sulfide ore deposits and various types Au ore deposits are concentrated in this zone. All the rocks and strata in this zone are mylonitized and show steep foliation due to lower greenschist facies metamorphism and ductile strike-slip deformation.

The Erqishi ductile strike-slip shear zone, extending E-W to NWW more than 1000 km, is exposed in Altai, Fuyun and Qinghe in the northernmost part of Xinjiang. It prolongates westward into Kazakhstan, where it is known as the Irtysh zone. It is composed of greenschist-amphibolite facies metamorphic carbonate, sandy-muddy rocks and volcanic rocks with age of Early Paleozoic. Tectonically, this zone has an affinity of Siberian continent, which is marked by *Isotelus*-

bearing Ordovician limestone-mudstone and *Tuvaella*-bearing Silurian sandy-muddy strata. All the rocks in this zone are sub-vertical due to ductile strike-slip deformation with high rates of deformation during Permian time.

It is worthy to notice that ductile "flower" structures are found in three zones mentioned above. Meter scale orthogneiss "flower" structure, exposed at Kanguer, consists of three parts: (a) an E-W axial zone, characterised by dextral ductile strike-slip fault with steeply foliations and sub-horizontal stretching lineations; (b) a southern flank of southward verging thrust, and (c) a northern flank of northward verging thrust. Both in the b and c, small ductile faults vary from sub-vertical in the lower part to very gentle in the upper part. Flinn value K is 0.38 for the south side and 0.47 for the north side. Athough this is only an associated extruded component during the strike-slip faulting, it indicates that the ductile strike-slip movement was ever violent.

2. Results of kinematic analysis

Lineations and foliations develop commonly in mylonitic rocks of ductile strike-slip shear zones mentioned above. The senses of shear for strike-slip deformations were constrained by various size kinematic criteria in the 20 geological sections and over 500 oriented microscopic thin-sections. All the thin sections were cut parallel to lineation and perpendicular to foliation.

The sense of shear was mainly determined by σ-type and δ-type porphyroclasts, S-C composite fabrics, rotated feldspar or quartz augens, asymmetric boudinages, displaced-apart structure and asymmetric rock slices arranged in an "en echelon" or oriented in an oblique direction to the mylonitic foliation. The quartz C-axis fabrics also are used to analyse sense of shear.

A conclusion is proposed that the Nalati-Bindaban-Weiya zone along the northern margin of the Centra Tianshan belongs to dextral ductile strike-slip shear zone, the Kanguer-Huangshan zone is dominantly occupied by dextral ductile strike-slip shear zone in which earlier top-to-the-north shear structures are preserved locally, and the Erqishi zone is a sinistral ductile strike-slip shear zone associated with some components of late dextral strike-slip shear.

3. Geochronological constraint

Field evidences and dating results from the literature provide chronological constraints. In the Late Carboniferous, the sinistral mylonitic deformation took place in the Erqishi-Irtysh shear zone in the northeastern part of Xinjiang and in Kazakhstan. During the Early Permian, a regional scale dextral event occurred in the Tianshan range and in whole northern Xinjiang. The ductile strike-slip shearing, associated with synchronous magmatic (granite, gabbro) emplacement, is concentrated in two periods, 290-280 Ma for sinistral movement and 270-245 Ma for dextral shear, respectively.

Numerous mica-schist were dated by $^{40}Ar/^{39}Ar$ on new-born muscovite and biotite grains. The dating data provide important information for Late Paleozoic and Early Mesozoic strike-slip events subsequent to Paleozoic accretional events in Central Asia. In the Tianshan, strike-slip shearing migrated from the north to the south. An earlier sinistral strike-slip shear occurred in the E-W Erqishi zone of Altai Region, dated at 281 ±8 Ma - 289 ± 4 Ma by $^{40}Ar/^{39}Ar$ on muscovite (Lurent-Charvet et al., 2002; Li et al., 2006). Subsequent dextral shearing took place in the period of 249±2 Ma - 244±3 Ma (Laurent-Charvet et al., 2003), which overprinted the earlier deformed structures in Qinghe and Fuyun, leading to the northward exhumation of a folded metamorphic zone. The Nalati-Bindaban-Weiya dextral strike-slip shear zone preserved abundant geochronological records around 270-250 Ma, for example, 269±5 Ma by $^{40}Ar/^{39}Ar$ on muscovite of orthogneiss in the southern Weiya (Shu et al., 1999, 2002), 272±4Ma by SHRIMP U-Pb on zircon of rhyolite in the Central Tianshan (Yang et al., 2006), 246±6Ma by U-Pb on zircon of granite near Weiya (Zhang et al., 2005). The Kanguer-Huangshan zone recorded a strong dextral strike-slip shear event around 260-

245 Ma, dated at 260±2 Ma 247±1 Ma, 243±2 Ma by $^{40}Ar/^{39}Ar$ on muscovite or biotite of mylonite at Kanguer (Wang et al., 2004, 2005).

4. Conclusion

1. Following Late Paleozoic collisional orogeny, a strong post-collisional ductile strike-slip deformation took place in Central Asia to cause thetermination of Tianshan Belt.

2. In Tianshan Belt, ductile strike-slip re-working is very common. Three most remarkable large-scale ductile strike-slip shear zones are recognized, namely the Nalati-Bindaban-Weiya zone along the northern margin of the Centra Tianshan, the Kanguer-Huangshan zone along the southern margin of the Turpan-Hami basin and the Erqishi zone in the northern part of Xinjiang.

3. kinematically, the Erqishi zone is a sinistral ductile strike-slip shear zone associated with some components of late dextral strike-slip shear, the Nalati-Bindaban-Weiya zone belongs to dextral ductile strike-slip shear zone, and the Kanguer-Huangshan zone is dominantly occupied by dextral ductile strike-slip shear structures.

4. The ductile strike-slip shearing was migrated from the north to the south. The earliest strike-slip shear took place in the E-W Erqishi zone, dated at 280-290 Ma, which was reprinted by a dextral shearing during 250-245Ma. The Nalati-Bindaban-Weiya dextral shear zone occurred around 270-250 Ma. The Kanguer-Huangshan zone recorded a strong dextral deformation around 260-245 Ma.

Acknowledgements

We thank the Bureau of National project 305 (Xinjiang Uygur autonomous Region, China) for many helps in the field. This research is supported by the National Basic Research Program of China (973 Program) (No. 2007CB411301), Program of China Bureau of Geological Survey (No.1212010611806) and by the Laboratoire de Geologie Structurale of Orleans University, France.

Late Carboniferous instead of Triassic collision of the Yili and the Tarim blocks along the southwestern margin of the Central Asia Orogenic belt: evidence from Cameca U–Pb dating of zircon from eclogites in the western Tianshan Mountains, NW China

Su Wen[1], Jun Gao[1], Reiner Klemd[2], Jilei Li[1], Xi Zhang[1], Xianhua Li[1], Nengsong Chen[3], Lu Zhang[3]

[1]Key Laboratory of Mineral Resources, Institute of Geology and Geophysics, Chinese Academy of Sciences, PO Box 9825, Beijing 100029, China

[2]GeoZentrum Nordbayern, Universität Erlangen, Schlossgarten 5a, 91054 Erlangen, Germany

[3]State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan, China

Zircon grains separated from an eclogite boudin intercalated within blueschists in western Tianshan (NW China) were investigated by Raman spectrometrical, Cathodoluminescence imaging and Cameca 1280 SIMS U–Pb age dating methods. They- usually comprise a thin homogeneous rim and an oscillatory core domain with or without a relic inherited core. Omphacite, phengite and rutile inclusions were identified within the rim domain of zircon grains, indicating that the rim had formed during peak eclogite-facies metamorphism. U-Pb zircon data record three distinct age populations: 2450 – 1956 Ma (inherited core), 454 ±12 – 449 ± 23 Ma (core) and 319.4 ± 4.6 – 318 ± 5.2 Ma (rim). These new high-precision ages in combination with geological field evidence suggest that continental arc rocks involving Precambrian basement materials were involved in the eclogite-facies metamorphism of the western Tianshan orogen. Furthermore the collision between the Tarim and Yili blocks along the southwestern margin of the Central Asia Orogenic belt must have occurred during the Late Carboniferous (*ca.* 320 Ma), and not Triassic (233 − 226 Ma) time, as recently suggested.

Synkinematic calc-alkaline and alkaline magmatism in Permian transcrustal mega-shear zones: implication to the post-orogenic tectonics, western Chinese Tianshan (Central Asia)

Wang Bo [1, 2], Dominique Cluzel [3], Liangshu Shu [1], Michel Faure [4], Jacques Charvet [4], Yan Chen [4], Bor-ming Jahn [2], Sebastien Meffre [5], Koen de Jong [6]

[1.] Department of Earth Sciences, Nanjing University, Nanjing, China
[2.] Institute of Earth Sciences, Academia Sinica, Taipei ROC
[3.] Pole Pluridisciplinaire de la Matière et de l'Environnement, Université de la Nouvelle-Calédonie, 98851 Nouméa, New Caledonia
[4.] Université d'Orléans, CNRS/INSU, Institut des Sciences de la Terre d'Orléans – UMR 6113, France
[5.] School of Earth Sciences, University of Tasmania, Hobart Tasmania 7001, Australia
[6.] School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea

Magmatic activity occurred in the western Chinese Tianshan from Early to Middle Permian along the mains strike-slip shear zones. New zircon U-Pb LA-ICPMS and $^{40}Ar/^{39}Ar$ data reveal a coincidence in time between regional wrench faulting (290-245 Ma) and granitoid emplacement (294-252 Ma). Field observations suggest that some of the Permian plutons show synkinematic fabrics. The whole rock geochemical features of the Permian granitoids indicate a co-occurrence of high-K calc-alkaline and alkaline magmatism. In other places (e.g. Bogda) of the North Tianshan, Early Permian alkaline magmatism occurred together with deep marine sedimentation within elongated troughs controlled by wrench faults. Therefore, in contrast with previous interpretations that forwarded continental rift or mantle plume hypotheses, the coexistence of diverse magmatic sources during the same tectonic episode suggests that post-orogenic lithosphere-scale transcurrent shear zones tightly controlled the magmatic activity, and the transition from convergent margin to intraplate anorogenic processes completed in Early-Middle Permian in the Western Chinese Tianshan.

References:

Wang B., Cluzel D., Shu L., Faure M., Charvet J., Chen Y., Meffre S., and de Jong K. 2009. Evolution of calc-alkaline to alkaline magmatism through Carboniferous convergence to Permian transcurrent tectonics, western Chinese Tianshan. Int J Earth Sci, doi: 10.1007/s00531-008-0408-y

de Jong K., Wang B., Faure M., Shu L.S., Cluzel D., Charvet J., Ruffert G., Chen Y., 2008. New $^{40}Ar/^{39}Ar$ age constraints on Late Palaezoic tectonic evolution of the western Tianshan (Xinjiang, northwestern China), with emphasis on Permian fluid ingress. Int J Earth Sci, doi: 10.1007/s00531-008-0338-8

Laurent-Charvet S., Charvet J., Monié P., Shu L.S., 2003. Late Paleozoic strike-slip shear zones in eastern Central Asia (NW China): new structural and geochronological data. Tectonics, 22, 1099-1101

Differential uplift of the Chinese Tianshan since the Cretaceous: constraints from sedimentary petrography and apatite fission-track dating

Wang Qingchen[1], Li Shuangjian[1,2], Du Zhili[1,3]

[1] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029

[2] Petroleum Exploration and Production Research Institute, SinoPec, Beijing 100083

[3] Tarim Petroleum Company, CNPC, Korla 841000

The Chinese Tianshan is one of the important international natural laboratories for studying continental geodynamics, but its uplift time, kinematics and mechanism of formation are key unresolved questions. In order to constrain the timing, kinematics and mechanism of uplift of the Chinese Tianshan, we applied sedimentary petrography and apatite fission-track dating to Cretaceous-Tertiary series from the northern Tarim Basin and the Tianshan Mountains. We collected and analyzed sandstone samples and detrital heavy mineral samples from the Kezilenuer-Kuqa profile (northern Tarim Basin) with a well-defined magnetostratigraphy. Our data indicate that maturity of both sandstone and detrital mineral decreased abruptly at the disconformity between the Upper and Lower Cretaceous, and decreased again after 15(-12) Ma. Composition changes in sandstone framework grains, heavy minerals and chemical composition of detrital garnet imply that the sediments in the northern Tarim Basin changed their provenance at 124 Ma, 26(-24) Ma and 15(-12) Ma, respectively. In addition, we collected and analyzed primary apatite samples from the South, Central and North Tianshan.

Our results show that the Chinese Tianshan underwent three phases of differential uplift. The first phase of uplift started at the southern Central Tianshan during the Early Cretaceous and propagated southward. The second phase of uplift started at the northern Central Tianshan during the Late Cretaceous and propagated also southward. The third phase of uplift started at the northern Central Tianshan during the Eocene and propagated both northward and southward. These differential uplifts have caused development of disconformity and drops in mineral maturity of detrital sediments in the northern Tarim Basin. Such a process is comparable to the action of a crowbar. When a crowbar (the Tarim Block) is inserted under one end of a flagstone (the South Tianshan), the end is lifted. When the crowbar pushes the flagstone (the Tarim Block) forward, the other end of the flagstone (the Central Tianshan) is lifted. With the help of reactivation of Paleozoic suture and fault, the Chinese Tianshan, acting as a huge flagstone, were lifted up step by step. The Tarim block, in fact, is but a “crowbar”, which was moving northwards when different microcontinents (i.e., Lhasa, Kohistan-Dras and India) collided to the southern margin of Asia.

Keywords: Differential uplift; Chinese Tianshan; Sandstone framework grains; Heavy minerals; Apatite fission-track

Paleozoic magmatism in the eastmost Tianshan orogenic belt, NW China and its implications for tectonic evolution

Wang Tao[1,2], Ying TONG[1], Shan LI[1], Zixia OUYANG[1], Yan-bin WANG[2] Da-wei HONG[1]

1. Institute of Geology, Chinese Academy of Geological Science, Beijing 100037, China
2. Beijing SHRIMP Center, Chinese Academy of Geological Science, Beijing 100037, China (e-mail: taowang@cags.net.cn)

The eastmost Tianshan Mountains, including eastern Tianshan in Xinjiang province and Beishan area in Gansu and inner Mongolia provinces, northwestern China, was one of key places to understand the development of the concept of Altaid collage of Central Asia (Sengor et al. 1993), or Central Asian Orogenic Belt (CAOB, Jahn et al. 2000). However, the orogenic history, particularly the early stage, in the region has not been well understood. Voluminous granitic gneisses and gneissic granitoids occur in this region. The nature and ages of these rocks play a key role in the study of the early stage of orogeny.

In this work, we undertook zircon U-Pb dating of Paleozoic plutons in order to better define the early magmatic and tectonic evolution of the eastmost Tianshan Mountains. The results revealed four Paleozoic granitic plutonic events at ca. 480-460 Ma, 450-420 Ma, and 420-380Ma, and 320-260 Ma.

The early-middle (480-420 Ma) Paleozoic granitoids mainly follow the tholeiitic and calc-alkaline trends, and they are mostly of I-type. The middle-late Paleozoic (420-380 Ma) are mostly I-type, some S-type and a few A-type features. Sr-Nd isotopic analyses indicate that the sources of the granitoids are quite complicated and contain both old continental and younger juvenile mantle-derived rocks. The early-middle granites are characterized by variable Isr values （0.7048 ~ 0.7123）, lower εNd（t） values（2.4 ~ -14.1）, and T_{DM} （0.92 ~ 3.17Ga）.The post-orogenic granites also show have variable Isr values （0.7016 ~ 0.7096）, εNd（t）values（-16.4 ~ +10.9）, and younger T_{DM} （0.38 ~ 2.65Ga）. These granites with high Isr values and low (negative) εNd（t） values confirm the existence of old continental fragments in the eastmost Tianshan.

The plutons of 480-460 Ma and 450-420 Ma show high deformation (foliation), and many of them occur as granitic gneisses, and the pluton of 420-380Ma exhibit weak or even little deformation These structural patterns of these plutons suggest that the regional deformation took place during 480 - 420 Ma. All the chemical, isotopic and structural features suggest that the plutons were mainly formed in a complex arc settings, and that the subduction and accretion processes in the Eastmost Tianshan Mountains at least began at ca. 480 Ma, or earlier, and culminated at ca. 450 - 420 Ma. In addition, the gabbro in the Hongliuhe Ophiolite was dated as 426 ± 2 Ma by method zircon TIMs dating (Wang et al., 2001, Yu et al., 2006) and 516 ± 7 Ma by zircon SHRIMP (Zhang and Guo, 2008) and the zircon U-Pb age of granite without deformation and metamorphism which intruded into the ophiolite is 405 ± 5 Ma (Zhang and Guo, 2008). This also suggests that orogen oceanic crust in the eastmost Tianshan formed during the early Cambrian, and closed before Emsian.

The late Paleozoic granitoids are characterized by I- and A-type, assouciated by mafic intrusions (dykes), consisting bimodal felsic and mafic plutons. The plutons show no deformation, and the rocks show features of granitoids in post-collision or post orogenic settings. We suggested this magmatism belongs to post-orogenic (accretional).

The evolution of the Paleozoic magmatism in mosteast Tianshan Mountains suggest that two stages of tectonic evolution: the subduction/collision took place during early-middle Paleozoic and transformed into a post-collision or a post-orogenic setting. These characteristics and magmatic evolution are slightly different from to those in Junggar and Altai orogens, i.e., the magmatism evolution in from synorogenic to post orogenic was older than that in Jungga and Altai orogens. We have not found successive accretion in the formation of the eastmost Tianshan, Junggar and Altai orogens.

Termination of the eastern Central Asian Orogenic Belt due to onset of Pacific-plate accretion in the latest Triassic-Early Jurassic

Wilde S.A. [1], F.Y. Wu[2], G.C. Zhao[3], J.B. Zhou[4] and Sklyarov, E.[5]

[1] The Institute for Geoscience Research, Department of Applied Geology, Curtin University of Technology, GPO Box U1987, Perth 6845, Australia

[2] Institute of Geology & Geophysics, Chinese Academy of Sciences, Qijiahuozi, PO Box 9825, Beijing 100029, China

[3] Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China

[4] College of Earth Sciences, Jilin University, Changchun 130061, China

[5] Institute of the Earth's Crust, Russian Academy of Sciences, Irkutsk, Russia

The nature and origin of micro-continental blocks within the Central Asian Orogenic Belt (CAOB) between the North China and Siberian cratons is currently under debate. The Jiamusi, Khanka and Bureya blocks make up the easternmost of these and new SHRIMP and ICP-MS U-Pb zircon data have recently been obtained. Data from para- and orthogneisses and granitoids confirm the close affinity of the Khanka and Jiamusi blocks, whilst the range in ages obtained from the Bureya Block (~1000 Ma to ~200 Ma) match those recorded by inherited and detrital zircons in the Jiamusi and Khanka blocks, supporting the view they have acted as a single crustal entity since the early Paleozoic; possibly since the Neoproterozoic. A major question remains as to their relationship to the CAOB: were they part of the Songliao Block to the west, were they accreted to the CAOB from the east, or were they once part of Siberia? A key component in this story is the Heilongjiang Complex, marking the western edge of the Jiamusi Massif. It represents a subduction-accretionary complex that locally attained blueschist facies conditions, and was potentially formed during collision of the combined Jiamusi/Khanka/Bureya block with the Songliao Block. SHRIMP U-Pb magmatic zircon ages from blueschist-facies metabasalts reveal ages at 260 and 210 Ma, defining eruption time as Late Permian and Late Triassic. Biotite and phengite from granitic gneiss and mica schist within the Heilongjiang Complex record late Early Jurassic $^{40}Ar/^{39}Ar$ metamorphic ages of between 184 and 174 Ma which, together with the basalt ages, determine the time of high-pressure metamorphism as Latest Triassic-Early Jurassic. With respect to the ultimate origin of the Jiamusi/Khanka/Bureya block, it has been proposed that it either came from a peri-Gondwana position or else from Siberia. It may have formed a discrete Gondwanan block that was never part of the CAOB until accreted as a result of Pacic Ocean subduction. However, since similar detrital zircon ages are reported from the Songliao Block, there may be a possible connection, with the combined Jiamusi/Khanka/Bureya block first rifting away and then re-accreting with the Songliao along a suture now represented by the present Jiayin-Mudanjiang Fault. With respect to Siberia, high-grade rocks similar to those of the Jiamusi/Khanka block, and with a metamorphic age of ~500 Ma, are recorded from the Sayang-Baikal Orogen of southern Siberia. A possible model is that the Jiamusi/Khanka/Bureya block rifted off from the Siberian margin, drifting south across the Paleo-Asian Ocean, to be swept westward by the onset of Pacific Ocean subduction. Against such a model is that virtually all other evidence suggests northward movement of the blocks to form the current Eurasian landmass. Whatever the ultimate origin of the combined Jiamusi/Khanka/Bureya block, our new results indicate that northward movement of the combined Mongolia-North China block toward Siberia had waning in the Late Triassic and that westward accretion resulting from Pacific subduction has dominated the tectonics of North China and Far East Russia since the Early Jurassic.

Paleozoic accretionary process of the Beishan orogenic collage: implication for the tectonics of southern Altaids

Xiao Wenjiao[1], Qigui Mao[2], Brian Windley[3], Chunming Han[1]

1. State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China. E-mail: wj-xiao@mail.igcas.ac.cn

2. *Beijing Institute of Geology for Mineral Resources, Beijing 100012, China*

3 *Department of Geology, University of Leicester, Leicester LE1 7RH, UK*

The Beishan orogenic collage is located in the key area connecting the Tien Shan to the west and the Inner Mongolian orogenic collages to the east. This paper provides an up-to-date synthesis of this orogenic collage and a new tectonic model to explain its accretionary evolution.

A continuous accretionary complex (Kokshaal-Kumishi) is defined here along the Southern Tien Shan, which separates a complicated huge subduction-related orogenic collage (southern part of the Altaids) to the north from southerly small-scale cratons (Tarim and Karakum). Cross-border correlation of this accretionary complex unravels a general southward and oceanward accretion in the early Palaeozoic to Permian as recorded by the juxtaposition of ophiolites, slices of ophiolitic mélanges, cherts, island arcs, olistostromes, blueschists, and turbidites, which are mainly Palaeozoic in age, with the youngest age constraint being the Permian. The northern orogenic collage is characterized by three Palaeozoic island arcs (Northern Ili, Issyk Kul, and Chatkal) located in the west, which may have amalgamated into a composite arc by either oroclinal bending or collision in the early Palaeozoic, and another two arcs (Dananhu and Xingxingxia) located in the east. The western composite arc and the eastern Dananhu, Yamansu, and Xingxingxia arcs formed a late Palaeozoic archipelago with multiple subduction zones. The docking of the southerly Tarim and Karakum cratons to this complicated late Palaeozoic archipelago and accretionary complex occurred in the late Permian-early Triassic, leading to a unique orogenic process along the western segment of the Central Asian Orogenic Belt.

Keywords**:** Tien Shan; Permian; Accretion; Central Asian Orogenic Belt

The UHP metamorphic petrology of coesite-bearing rocks from Western Tianshan, China

Zhang Lifei[1], Zeng Lu[1], Jinxue Du[1] and Kurt Bucher[2]
1School of Earth and Space Sciences, Peking University, Beijing 100871, China
2 Institute of Mineralogy, University of Freiburg, Alberstrasse 23b, D-79104 Freiburg, Germany

Detailed petrological analysis was carried out on rocks for the HP-LT ophiolite exposed along the Habutengsu River, in the northern part of HP-UHP belt of western Tianshan. Well preserved coesite inclusions in garnet have been recognized in both eclogitic micaschists and basaltic eclogites, indicative of *in situ* UHP metamorphism in this area.

The eclogitic micaschists contain white mica (>30%), garnet, omphacite, coesite/quartz, barroisite and graphite. The coesite grains rimmed by quartz exhibit distinct radial cracks in the host garnet, while some are monomineralic coesite, showing no difference to quartz optically but distinguished by Raman spectroscopy. All of the coesite shows its most intensive characteristic band at *ca.* 522 cm^{-1} and other subsidiary bands at 428, 326, 271, 178, 151 and 121 cm^{-1}.

Omphacite is Jd_{40-55}, with invariably low Fe. Most of the white mica is altered low-K phengite. Garnet has a flat Ca-poor core ($Alm_{75}Pyr_{11}Grs_{8}Sps_{6}$) in sharp contact to and surrounded by a Ca-rich mantle. Multistage growth of garnet is indicated by the BSE images and compositional profiles. The Ca-rich garnet mantles overgrowing the old embayed (or oval-shaped) cores contain inclusions of omphacite. These compositional features reflect a metasomatic process during garnet growth. It is suggested that the two garnet domains have grown in different compositions of the rock matrix. The UHP eclogitic schists have a Ca-poor pelitic precursor similar to the nearby schists and metasomatism contributed to the formation of basic eclogite facies assemblages in Ca-enriched micaschists.

The basaltic eclogites are mainly composed of garnet, omphacite, paragonite, glaucophane, barroisite and graphite. The coarse-grained euhedral garnet contains omphacite, glaucophane, chlorite, clinozoisite, paragonite, rutile, ilmenite, coesite/quartz and graphite. Coesite rimmed by quartz was recognized optically and confirmed by Raman spectroscopy. The microtextures of the transformations between coesite, chalcedony and quartz are well displayed in the CL images. Within the garnet, coexisting clinozoisite and paragonite is interpreted as pseudomorphs after lawsonite. The absence of a systematic variation of the Jd-content of omphacite inclusions in garnet porphyroblasts cores reflects the thorough overprint under eclogite facies conditions. Garnet porphyroblasts generally show a flat compositional profile, although Ca and Mg/(Fe+Mg) rapidly increase towards the narrow rim, in the vicinity of which coesite was found.

Using Grt-Cpx geothermometery and the compositions of omphacite inclusions close to coesite, *ca.* 500°C were calculated at 2.6 GPa for the metabasites (somewhat lower than in previous studies). The *P-T* estimate is consistent with metamorphic conditions constrained by preliminary assemblage stability modeling for basaltic eclogites and their surrounding micaschists using DOMINO/THERIAK software. The *P-T* conditions represent the return point of the Habutengsu ophiolite during the Triassic subduction in the Tianshan orogeny. It is one of the very few documented UHP ophiolites globally and demonstrates that deeply subducted oceanic lithosphere may be returned to the surface in rare instance.

CONTRIBUTORS LIST

Cameron Quinn (cameron.quinn@dpi.nsw.gov.au), Ordovician continental growth in the southern Tasmanides, eastern Australia, by the recycling of continental detritus

Charvet J. (ISTO, Université d'Orléans, Orléans, France, jacques.charvet@univ-orleans.fr), Shu L.S., Laurent-Charvet S., Wang B., Faure M., Cluzel D., Chen Y., de Jong K. Paleozoic tectonic and geodynamic evolution of Chinese Tianshan belt

Choulet F. (ISTO, Université d'Orléans, Orléans, France, Flavien.choulet@univ-orleans.fr), Y. Chen, B. Wang, M. Faure, D. Cluzel, W. Lin, J. Charvet and B. Xu, New paleomagnetic study of Late Paleozoic rocks of the Junggar Basin (Northwestern China) and insights for the geodynamic evolution of Central Asia

Gao Jun (Inst. Geology and Geophys, CAS, gaojun@mail.igcas.ac.cn), Late Carboniferous instead of Triassic collision of the Yili and the Tarim blocks along the southwestern margin of the Central Asia Orogenic belt: evidence from Cameca U–Pb dating of zircon from eclogites in the western Tianshan Mountains, NW China

Glen Richard (Glen:dick.glen@dpi.nsw.gov.au), Ordovician continental growth in the southern Tasmanides, eastern Australia by the recycling of older detritus

Guo Zhaojie (Peking University, China, zjguo@pku.edu.cn), Wu Chaodong, Zhang Zhicheng, Mesozoic-Cenozoic relationships between Tianshan Mountain and peripheral basins: evidences from sedimentology and exhumation of Jurassic in Houxia area, Urumch

Jahn B.M. (Institute of Earth Sciences, Academia Sinica, Nangang, Taipei 11529, Taiwan, jahn@earth.sinica.edu.tw), Peralkaline Granitoid Magmatism in the Mongolian-Transbaikalian Belt: Evolution, Petrogenesis and Tectonic Significance

Jahn Bor-ming (Institute of Earth Sciences, Academia Sinica, Nangang, Taipei 11529, Taiwan, jahn@earth.sinica.edu.tw) and Boris A. Litvinovsky, Peralkaline granitoid magmatism in the Mongolian-Transbaikalian Belt: evolution, petrogenesis and implications for crustal growth

Kroner, A. (Institut für Geowissenschaften, Universit?t Mainz, kroener@mail.uni-mainz.de), Alexeiev, D.V., Hegner, E, Corsini, M., Mikolaichuk, A., Xia, X., Zack, T., Windley, B.F., Sun, M., Rojas-Agramonte, Y.1, Liu, D., New zircon, Sm-Nd, and Ar-Ar ages for Precambrian and Palaeozoic rocks from the Tianshan orogenic belt in Kyrgyzstan and disappearance of the Archaean

Li Zhong (Inst. Geol. Geophys, China, lizhong@mail.igcas.ac.cn), Guocan Wang, Devonian-Carboniferous tectonic evolutional framework of the Chinese southwestern Tianshan: constraints from depositional records

Lin Wei (Inst. Geol. Geophys, China, linwei@mail.igcas.ac.cn), Michel Faure, Yonghong Shi, Qingchen Wang, Zhong Li, Paleozoic tectonics of the south-western Chinese Tianshan: New insights from a structural study of the high-pressure/low-temperature metamorphic belt

Rojas-Agramonte Y. (University of Mainz, Germany, rojas@uni-mainz.de), A. Kröner, A. García-Casco, T. Kemp, M. Pérez, A. Fonseca-Montero, Dunyi Liu, Geochemistry and SHRIMP zircon ages of granitoid rocks from the northern ophiolote mélange of Central Cuba: implications for late Cretaceous Caribbean geology

Rosenbaum Gideon (The University of Queensland, Australia, g.rosenbaum@uq.edu.au), Subduction rollback, slab tear faults and oroclinal bending

Scheltens Mark (, Utrecht University, The Netherlands, lfzhang@pku.edu.cn) and LiFei Zhang, Southwestern Tianshan: A structural analysis and its complications for the geodynamic evolution

Seltmann Reimar (Natural History Museum, UK, r.seltmann@nhm.ac.uk) & Alla Dolgopolova, Gold-copper giants of central Eurasia: isolated hot spots vs tracking metallogenic belts that formed during orogenic cycles

Shu Liangshu (Nanjing University, lsshu2003@yahoo.com.cn), Charvet Jacques, Wang Bo, Faure Michel, Studies of three Late Paleozoic strike-slip zones in the Tianshan region, NW China

Su Wen (Institute of Geology and Geophysics, gaojun@mail.igcas.ac.cn), Jun Gao, Reiner Klemd, Jilei Li, Xi Zhang, Xianhua Li, Nengsong Chen, Lu Zhang, Late Carboniferous instead of Triassic collision of the Yili and the Tarim blocks along the southwestern margin of the Central Asia Orogenic belt: evidence from Cameca U?Pb dating of zircon from eclogites in the western Tianshan Mountains, NW China

Wang Bo (Nanjing University, bowang@earth.sinica.edu.tw) Dominique Cluzel, Liangshu Shu, Michel Faure, Jacques Charvet, Yan Chen, Bor-ming Jahn, Sebastien Meffre 5, Koen de Jong, Synkinematic calc-alkaline and alkaline magmatism in Permian transcrustal mega-shear zones: implication to the post-orogenic tectonics, western Chinese Tianshan (Central Asia)

Wang Qingchen (Institute of Geology and Geophysics, qcwang@mail.iggcas.ac.cn), Li Shuangjian, Du Zhili, Differential uplift of the Chinese Tianshan since the Cretaceous: constraints from sedimentary petrography and apatite fission-track dating

Wang Tao (Chinese Academy of Geosciences, taowang@cags.net.cn), Paleozoic magmatism in the east most Tianshan orogenic belt, NW China and its implications for tectonic evolution

Wilde S.A., (Curtin University of Technology, Australia, S.Wilde@curtin.edu.au), F.Y. Wu, G.C. Zhao, J.B. Zhou and Sklyarov, E., Termination of the eastern Central Asian Orogenic Belt due to onset of Pacific-plate accretion in the latest Triassic-Early Jurassic

Xiao Wenjiao (Institute of Geology and Geophysics, wj-xiao@mail.igcas.ac.cn), Qigui Mao, Brian Windley, Chunming Han, Paleozoic accretionary process of the Beishan orogenic collage: implication for the tectonics of southern Altaids

Zhang Lifei (Peking University, lfzhang@pku.edu.cn), Zeng Lu, Jinxue Du and Kurt Bucher, The UHP metamorphic petrology of coesite-bearing rocks from Western Tianshan, China